CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 68 OCTOBER 1982 NUMBER 4

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CALIFORNIA FISH AND GAME

VOLUME 68 OCTOBER 1982 NUMBER 4

Published Quarterly by

STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF FISH AND GAME

—LDA—

CHANGE OF EDITORSHIP

With this issue, Perry L. Herrgesell, Environmental Services Supervisor with the Bay-Delta Fishery Project, assumes the duties of Editor-in-Chief of *California Fish and Game*.

Dr. Herrgesell's assumption of the editorship follows the Department's policy of rotating the editorship between staff members representing Marine Resources, Inland Fisheries, Wildlife Management, and the Bay-Delta Project.

Dr. Herrgesell has been with the Department for the past 8 years. During this time he supervised water quality programs, a limnological laboratory, and the Delta Outflow/San Francisco Bay Study. He has published scientific papers in various national and international journals, professional association bulletins, national conference proceedings, and in Departmental administrative reports.

Under his guidance, the Journal will continue its policy of presenting to the public the results of scientific investigations as they relate to management programs and the conservation of California fish and wildlife resources. Dr. Herrgesell will strive to maintain the excellent reputation the Journal has gained over the last 68 years and when possible, will augment its credibility in the scientific community.

Dr. Herrgesell will be ably assisted in his duties by six associate editors: Jack Hansen, Inland Fisheries; Robert Lea, Marine Resources; Bruce Browning, Wildlife Management; Ken Hashagen, Anadromous Fisheries; Don Stevens, Striped Bass, Sturgeon and Shad; and Kim McCleneghan, Environmental Services.

To Mr. Hashagen, Editor-in-Chief the past 4 years, we wish to express our appreciation for the job well done. *E. C. Fullerton, Director, California Department of Fish and Game.*

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LIFE HISTORY, DISTRIBUTION, AND STATUS OF *PACIFASTACUS FORTIS* (DECAPODA: ASTACIDAE) [1]

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The life history and distribution of *Pacifastacus fortis* were studied during 1978, 1979, and 1980. Crayfish were collected by snorkeling, then sexed, measured, and returned to the water unharmed. Surveys supported earlier findings that *P. fortis* occurs only in the midreaches of Pit River and its tributaries in northeastern Shasta County, California. The preferred habitat of *P. fortis* is among rocks on clean, firm sand or gravel substrate in cool, spring-fed lakes and streams with relatively little annual temperature fluctuation. The sex ratio of *P. fortis* is approximately 1:1. Copulation and egg extrusion occur in the fall and young are released the following July. Fecundity is low with only 10–70 eggs extruded per female. The growing season for *P. fortis* is from April to October. *Pacifastacus fortis* grows slowly, is only 8–10 mm total carapace length (TCL) at the end of the first growing season and probably does not reach reproductive maturity (at about 28 mm TCL) until its fifth year. Circumstancial evidence suggests that *P. fortis* is a carnivore or browser rather than an omnivorous scavenger like *P. leniusculus. Pacifastacus fortis* is nocturnal and tolerant of the proximity of other crayfish. Commensal oligochaetes (Branchiobdellidae) and ostracods (Entocytheridae) are common on *P. fortis. Pacifastacus fortis* is threatened by competition with the exotic crayfishes, *Orconectes virilis* and *P. leniusculus* which are expanding their range within the area, agricultural and water development and an increasing human population. Because of these threats and its restricted distribution *P. fortis* has ben designated a Rare species by the California Fish and Game Commission.

INTRODUCTION

Only three crayfish species are native to California. *Pacifastacus nigrescens* (Stimpson) was once common in the San Francisco Bay area but has probably been extinct since the early 1900's. *Pacifastacus leniusculus klamathensis* (Stimpson), probably originally confined in California only to streams from the Klamath River drainage northward, has, along with other subspecies of *P. leniusculus,* been widely introduced throughout the State. Widespread and indiscriminate introductions of several subspecies of *P. leniusculus* have resulted in overlapping ranges and interbreeding to such an extent that Hobbs (1972) questions whether any subspecies of *P. leniusculus* could be recognized. *Pacifastacus fortis* (Faxon) occurs only in northeastern Shasta County, California.

In 1975, the United States Fish and Wildlife Service commissioned a study of rare and potentially threatened or endangered crayfishes in the United States (Bouchard 1976, 1977*a*). *Pacifastacus fortis* was found only in the Fall River and

[1] Accepted for publication June 1981.
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Hat Creek systems and Sucker Springs, all tributaries to Pit River in northeastern Shasta County. Bouchard (1976) reported the invasion of the midreaches of Pit River by a more advanced and aggressive crayfish, *Orconectes virilis* (Hagen), from east of the continental divide in North America. Introduction of this species in several eastern states outside its original range has resulted in the displacement of native crayfishes (Schwartz, Rubelmann, and Allison 1963; Bouchard 1975). Threats to *P. fortis* resulting from the encroachment on its limited range by this exotic (Bouchard 1976, 1978) prompted the U.S. Fish and Wildlife Service to propose that it be listed as a Threatened species under the Endangered Species Act of 1973 (Federal Register 42:2507, 1977). The California Fish and Game Commission, in June 1980, designated *P. fortis* a Rare species under state law.

In the summer of 1978, the California Department of Fish and Game (CDFG) and U.S. Forest Service initiated studies to further determine the distribution of *P. fortis* and to gain biological and ecological information necessary for its conservation. This report presents the results of these studies, summarizes the historical and taxonomic data on *P. fortis,* and evaluates its present status.

TAXONOMY

Pacifastacus (Hobbsastacus) fortis (Faxon 1914)

Astacus nigrescens fortis Faxon 1914
Pacifastacus nigrescens fortis Bott 1950 (by implication)
Pacifastacus fortis Hobbs 1972
Pacifastacus (Hobbsastacus) fortis Bouchard 1977*b*

Pacifastacus fortis was originally described as *Astacus nigrescens fortis* by Faxon (1914) from specimens collected from Fall River, at Fall River Mills and from Hat Creek near Cassel (Bouchard 1977*a*). Bott (1950) revised the subfamily Astacinae creating the new genus *Pacifastacus,* for the mostly western North American species of the subfamily, limiting the name *Astacus* to some of the Eurasian species. Hobbs (1974*a*) erected the family Cambaridae to encompass those crayfishes in which the males exhibit a cyclic dimorphism, thereby leaving the remaining members of the former subfamily Astacinae to constitute the family Astacidae. The genus *Pacifastacus* was later subdivided into two subgenera, *Pacifastacus* and *Hobbsastacus,* by Bouchard (1977*b*). *Pacifastacus fortis* which Hobbs (1972) elevated to species status belongs to the subgenus *Hobbsastacus.*

COMMON NAMES

Most invertebrate species, with the exception of butterflies, mussels, and commercial and sport species, do not have common names. Along with concern for the protection of certain species legally designated as Rare, Threatened, or Endangered has developed a tendency by federal and state agencies to coin common names for species lacking them. Thus, the U.S. Fish and Wildlife Service coined "placid crayfish" as a common name for *P. fortis* when it proposed this species for Threatened status (Federal Register 42:2507, 1977). Similarly the California Fish and Game Commission referred to *P. fortis* as the "Shasta crayfish" when it placed this species on its list of Rare species. Although it may be argued whether a common name for *P. fortis* will ever gain widespread acceptance it seems likely that one will persist among government agencies concerned with the protection and management of this species.

Funk and Wagnalls Standard College Dictionary (1968) defines placid as "Having a smooth unruffled surface or nature; unruffled; calm." This adjective is misleading when applied to *P. fortis*. Therefore, when a common name is desired for *P. fortis,* we suggest that "Shasta crayfish" be utilized for this species since it is found only in Shasta County, California.

DESCRIPTION

Pacifastacus fortis is a small- to medium-sized crayfish; adults are 25 to 50 mm total carapace length (TCL). The usual color is dark brownish green to dark brown dorsally and bright orange ventrally. Occasional blue-green to bright blue individuals are encountered. These blue individuals are a light salmon color below. Some specimens from Fall River are dark orange brown dorsally and bright red ventrally, especially on the chelae. All color forms but the blue are cryptic among the volcanic rubble of their habitat. Species of the subgenus *Hobbsastacus* [*P. fortis, P. nigrescens, P. connectens* (Faxon), and *P. gambelii* (Girard)] presumably shared a common Pliocene ancestor, *P. chenoderma* (Cope) (Rathbun 1926; Miller 1960; Hobbs 1974*b*). They are easily distinguished from the subgenus *Pacifastacus,* whose ancestors more recently invaded fresh water (Miller 1960), by the denticulate (toothed) margin of their rostra (Figure 1). Within its subgenus *P. fortis* can be distinguished from *P. connectens* (native to Idaho, northern Nevada, northern Utah, and eastern Oregon) and *P. gambelii* (essentially a Rocky Mountains species) by the absence of setal patches on its chelae. Both *P. connectens* and *P. gambelii* have two conspicuous clusters of setae on the dorsal surfaces of each chela (see Hobbs 1972). The key differences between *P. fortis* and *P. nigrescens* are less obvious and rely on the relative length/width ratios of their chelae. (The chelae of *P. nigrescens* are relatively long and narrow compared to the shorter more robust chelae of *P. fortis.*) Since *P. nigrescens,* a San Francisco Bay area endemic, has not been collected for more than 50 years and is presumed to be extinct, the differences between these species are likely of academic interest only. Keys assisting in the identification of these and other California species, including the exotics *Procambarus clarkii* (Girard) and *Orconectes virilis,* are presented in Riegel (1959) and Hobbs (1972).

Pacifastacus fortis is sexually dimorphic. Males have narrower abdomens and larger chelae than females. Also the first two pairs of pleopods (swimmerets) of the males are heavily sclerotized and modified for sperm transfer. These structures provide an easy means of sexing individuals, since in the females all pleopods are unmodified. Specialization of the male pleopods begins early and sex can be determined in some individuals as small as 10 mm (TCL).

METHODS

Known and potential *P. fortis* habitats were surveyed from May to August 1978 (Figure 2). Lake Britton, Hat Creek, Fall River, Pit River between the Fall River confluence and Lake Britton, and their tributaries were sampled by snorkeling, trapping, and turning stones. Additional sites were sampled downstream from Britton Dam in the main channel of Pit River and on Kosk Creek (Figure 2).

The *P. fortis* population at Crystal Lake (Hat Creek subdrainage) was sampled from June 1978 through November 1979 at approximately monthly intervals. No sampling was undertaken during December 1978 through February 1979. On

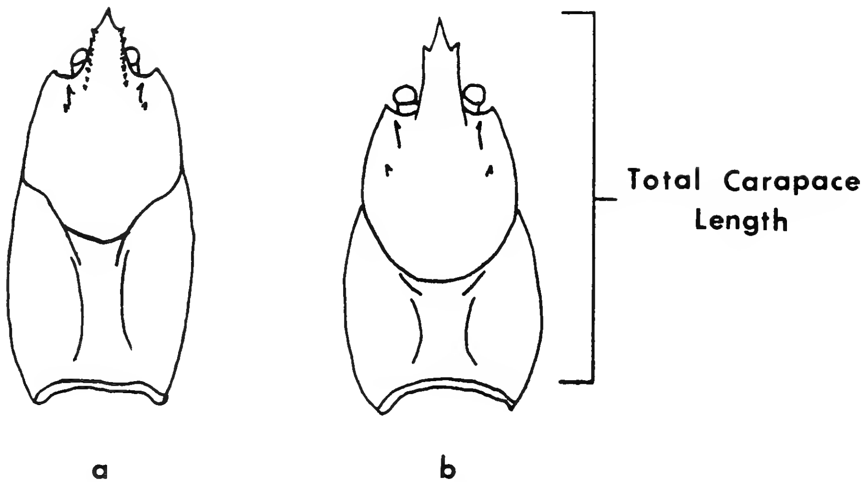

FIGURE 1. Dorsal view of the cephalothorax of *Pacifastacus fortis* (a) and *Pacifastacus leniusculus* (b).

each trip crayfish were collected by snorkeling, sexed, total carapace length measured, and reproductive condition and molt status recorded. Handling small individuals without injuring them is difficult under field conditions; therefore, sex was routinely determined only for individuals over 13 mm TCL. After data were collected, the crayfish were returned to the lake. Several additional sampling trips to Pit River, Hat Creek, and Fall River were undertaken in the spring and early summer 1980.

DISTRIBUTION

Our survey supported earlier findings that *P. fortis* occurs only in the Fall River and Hat Creek subdrainages and that reach of Pit River which connects them. Several new sites were recorded but all these were within the range previously delimited by Bouchard (1976, 1978). Populations exist in Crystal, Baum, and Rising River lakes in the Hat Creek subdrainage; Fall River, Big Lake, Spring, Squaw, and Lava creeks, and Crystal and Rainbow springs in the Fall River subdrainage; and in Sucker Springs, a tributary of Pit River that lies between the two subdrainages (Figure 2).

No *P. fortis* were found in Bear Creek, a major tributary to Fall River near its source, nor were any observed in Hat Creek upstream from the Rising River Lake area or from Pit River proper, except for a single juvenile which was found in Pit River several hundred metres upstream from the confluence of the Sucker Springs outflow. The presence of this juvenile fosters hope that the species may exist in low density in Pit River; however, it seems more likely that this individual was a waif from the Sucker Springs population. None of the other major tributaries of the midreaches of Pit River support *P. fortis,* although the introduced eastern crayfish, *Orconectes virilis,* is common in Pit River from Lake Britton upstream to Pit River Falls and *P. leniusculus* is locally abundant in Burney Creek and Baum Lake (Daniels 1980). Daniels (1980) also reported that a single

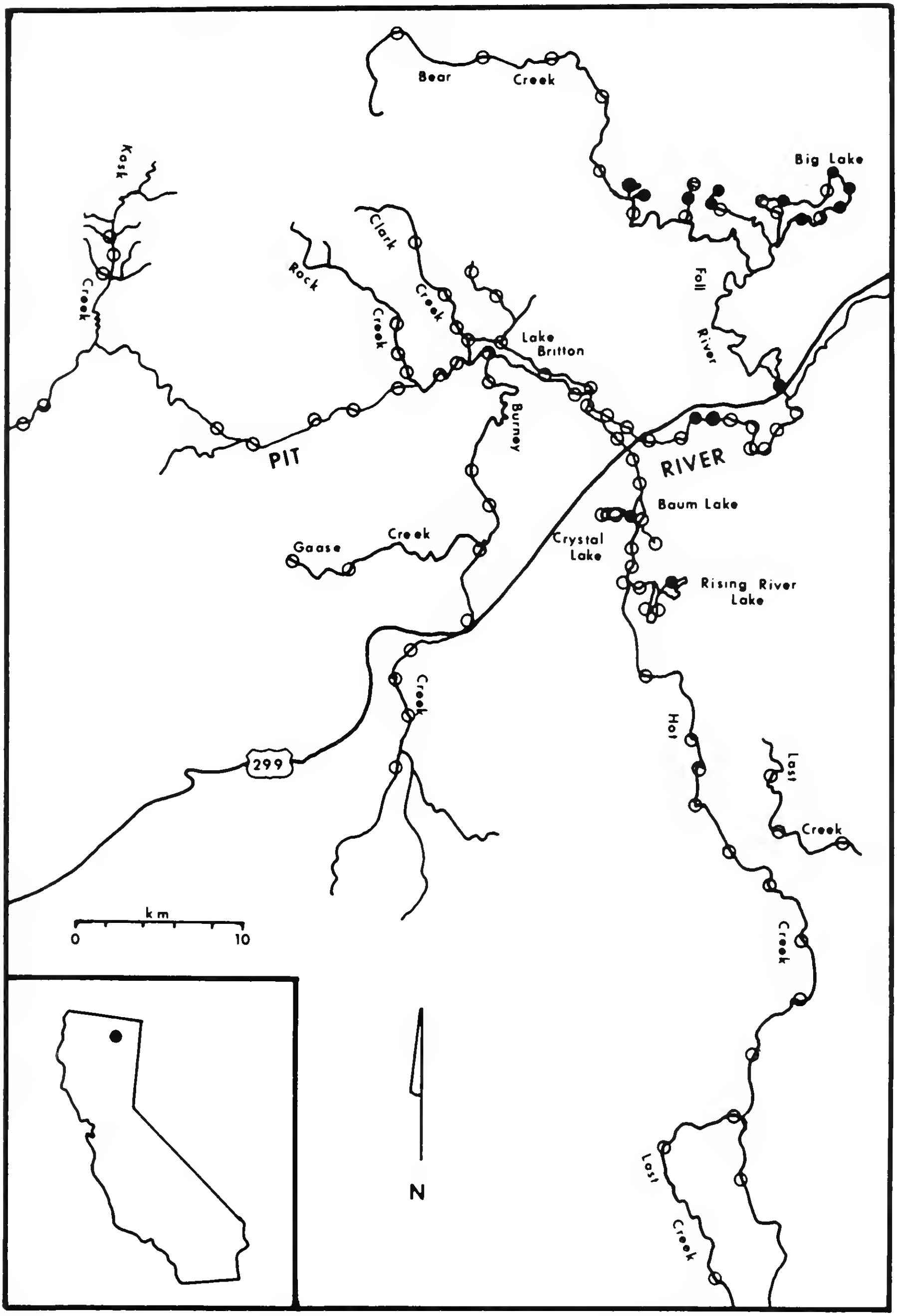

FIGURE 2. Distribution of *Pacifastacus fortis*. Midreaches of Pit River, northeastern Shasta County, California. Solid circles are stations where *P. fortis* was found. Empty circles are stations where *P. fortis* was absent.

female *P. leniusculus* was collected in Crystal Lake in November 1978. Subsequently we found *P. leniusculus* of both sexes in Crystal Lake and lower Hat Creek and lower Fall River, indicating that it is making further inroads into the range of *P. fortis.*

Pacifastacus fortis is apparently a relict species, its ancestral range perhaps reduced by geological and related climatic changes (Bouchard 1978). We have no evidence that *P. fortis* has had a wider range during historic times. We were unable to find living *P. fortis* a single dead individual was observed) or habitat which appeared suitable for it in Fall River at Fall River Mills (the type-locality). This and other sections of the Pit River drainage have been changed markedly within historic times. Development of the area for agricultural purposes, particularly diking and diversion of water, has altered the original habitat. The construction of several power plants and reservoirs has changed much of the Pit River system from wild a free-flowing streams to a series of interconnected impoundments subject to periodic (and unseasonal) fluctuations in water flow. Even more recently northeastern Shasta County has suffered a major increase in human population and use with a corresponding increase in demand for development and "improvement" of the limited resources of the area. As we will discuss below, *P. fortis* is narrowly adapted to the special environmental conditions found historically in the midreaches of the Pit River system. All of the above activities have altered the area and reduced the habitat available to *P. fortis* and other native species.

HABITAT

Pacifastacus fortis occurs in cool, clear, spring-fed lakes and streams. Most populations are found at or near a spring source (e.g., Crystal Lake, Thousand Springs, Rainbow Springs, and Sucker Springs). These waters show relatively little annual fluctuation in temperatures. The water temperatures at Rainbow Springs were 11.4° C in late July 1979 and 10.5° C in January 1980 (M. Rode, Fishery Biologist, Calif. Dept. Fish and Game, pers. commun.). Similarly relatively stable temperatures are reported for Thousand Springs by a longtime property owner, Dr. V. S. Meyer. Water temperatures taken 0.5 m below the surface at the east side of Crystal Lake near the outflow range from 11 to 16° C during the study period.

Pacifastacus fortis was found only under rocks larger than 7.5 cm in diameter. These rocks were usually on clean, firm, sand or gravel substrate as reported by Bouchard (1977*a*); however, in Crystal Lake a fine, probably organic, material 1 to 3 cm thick covered most of the bottom. This material reduced visibility and the efficiency of crayfish capture by stone turning to zero, especially from March through May.

Emergent vegetation (*Typha* sp. and *Scirpus* sp.) is present in some areas and water milfoil (*Myriophyllum* sp.) also occurs locally; however, *P. fortis* was not observed to utilize either plant type for cover. Where *P. fortis* is most abundant, plants are absent. By contrast, its congener, *P. leniusculus,* is often found among submerged vegetation. The negative correlation between *P. fortis* and the presence of vegetation (Daniels 1980) may represent a lack of suitable substrate for plants in areas where rocky substrate provides favorable habitat for the crayfish rather than actual avoidance of vegetation.

Pacifastacus fortis abundance is positively correlated with depth, distance from shore, and mean stream width and percent pool (Daniels 1980). By far the most important habitat requirement appears to be the presence of adequate rocky rubble for cover. Some other correlations (e.g., the negative correlation with shade) (Daniels 1980) may be artifactual and result from association with the presence or absence of suitable rocky cover.

Pacifastacus fortis does exhibit some adaptability in habitat utilization. At Sucker Springs, no natural habitat remains and the crayfish are living within the rocky wall of a fish raceway. In Lava Creek, where volcanic rubble is abundant but fine sand or gravel is uncommon, *P. fortis* is present in small numbers. At this locality an ovigerous (egg-bearing) female (37.3 mm TCL) was found in the cavity of a cow leg bone lying on a patch of sand.

In general the habitat of *P. fortis* can be described as follows: cool, clear, moderate-sized bodies of water with low gradient, little annual temperature variation, rubble on firm sandy or gravelly bottom, and little aquatic vegation. Bouchard (1977*a*) has previously pointed out that all known populations occur below 1,036 m elevation.

BIOLOGY AND LIFE HISTORY

Sex Ratio

The sex ratio of *P. fortis,* at least in Crystal Lake, is nearly 1:1. On most trips slightly more females were collected than males; however, on only two occasions was this difference significant at the 0.1 level (Table 1). Similar results were obtained whether analysis included all sexed individuals or only reproductively mature individuals (>27 mm TCL).

TABLE 1. Sex Ratio of *Pacifastacus fortis* ($\geq$ 15 mm CL) at Crystal Lake, Shasta County, California in 1978 and 1979

Date	*Males*	*Females*	*Total*	X^2	*Probability*
26 June 1978	26	32	58	0.62	0.3–0.5
25 July 1978	41	58	99	2.91	0.05–0.1
29 August 1978	45	50	95	0.26	0.5–0.7
12 September 1978	20	36	56	4.57	0.025–0.05
21 October 1978	22	20	42	0.09	0.7–0.8
7 November 1978	26	32	58	0.62	0.3–0.5
14 March 1979	17	12	29	0.86	0.3–0.5
19 April 1979	6	13	19	2.57	0.1–0.2
31 May 1979	22	21	43	0.23	0.5–0.7
25 June 1979	14	21	35	1.40	0.2–0.3
20 July 1979	35	40	75	0.33	0.5–0.7
5 October 1979	53	44	97	0.83	0.3–0.5
8 November 1979	35	43	78	0.82	0.3–0.5

Reproduction

Copulation, as evidenced by the presence of spermatophores on female *P. fortis,* occurs in late September and October after the final molt of the season, and eggs are extruded in late October and November. No ovigerous females were observed on 21 October 1978 or 5 October 1979, but on 7 November 1978 and 8 November 1979, 53% and 68%, respectively, of all females observed were carrying eggs. In March 1979, 86% of the females were ovigerous. No ovigerous

crayfish under 28 mm TCL was observed, thus we tentatively conclude that these crayfish are about 28 mm TCL when they reach sexual maturity. No attempt was made to determine the presence of ovarian eggs or the size of males at reproductive maturity. Mason (1975) determined that size at maturity was similar for both sexes in *P. leniusculus.*

Since it is difficult to count eggs or young on living crayfish under field conditions, fecundity estimates are based on a small number of individuals. These data indicate that relatively few eggs (10 to 70) are extruded (Table 2) and that fecundity increases with size (Figure 3). The eggs of *P. fortis* are relatively large (2.8 to 3.7 mm in diameter).

TABLE 2. Fecundity of *Pacifastacus fortis*

Site [1]	*Date*	*Number measured*	*Mean number of eggs*	*SD*	*Range*	*Source*
SS	9 November 1974	1	63.0[2]	–	–	Bouchard 1977*a*
TS	9 November 1974	2	34.0	–	25–43	Bouchard 1977*a*
	19 March 1980	3	32.3	12.4	18–40	CDFG unpubl.
CL	11 November 1974	1	35.0[2]	–	–	Bouchard 1977*a*
	7 November 1978	10	39.0	5.9	29–50	This study
	8 November 1979	19	39.2	12.7	14–66	This study
Total		36	38.8	11.3	14–66	

[1] SS = Sucker Springs; TS = Thousand Springs; CL = Crystal Lake; CDFG = California Department of Fish and Game

[2] Actual count

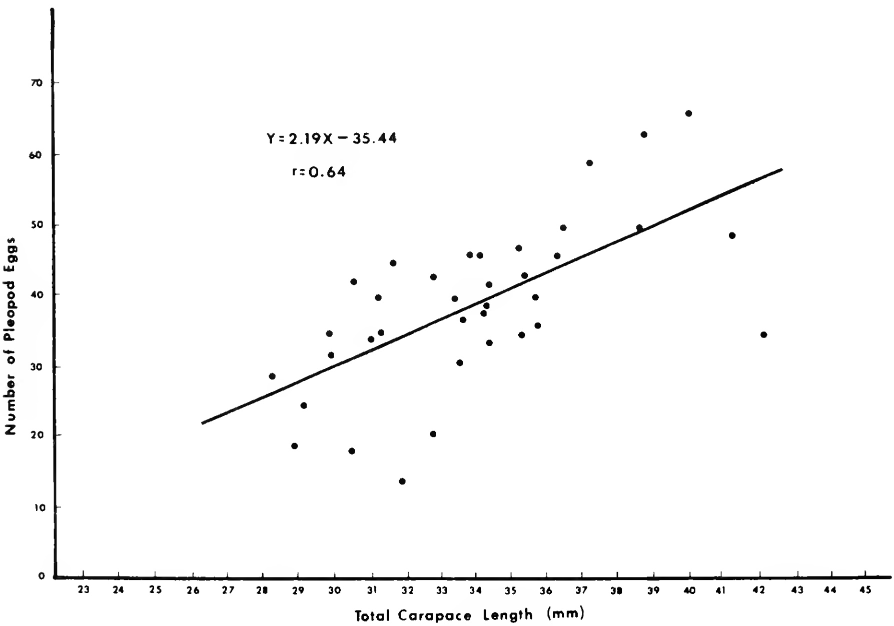

FIGURE 3. Size/fecundity relationships of *Pacifastacus fortis.*

Some apparently mature females were without eggs during the egg bearing season. Miller (1960) has reported that some female *P. leniusculus* do not bear eggs every year. This may be true for *P. fortis* as well. On rare occasions fungal growth on the pleopods indicated that the eggs had been infertile, diseased, or otherwise unfertilized. Vey (1977) has reported that eggs of *P. leniusculus* can be killed by a fungal infection which apparently does not affect the female.

Eggs show no external evidence of development during winter, but by April cleavage is visible to the unaided eye and by the end of May hatching has begun. The young crayfish pass through stages very similar to those described by Andrews (1907) for *P. leniusculus.* The first instar (Figure 4) is about 5 mm TCL and is attached to the female's pleopods by a thread connected to its telson. The second instar is attained by late June. At this stage young crayfish are 5 to 6 mm TCL and cling to their mothers with their chelae. If a female is not carefully handled at this stage some young may be dislodged. The fate of these individuals is unknown. We observed that when they are placed in a bucket of water containing their mother and other *P. fortis,* dislodged young attach themselves to the first female they encounter. The third instar (about 7 to 8 mm TCL) is reached by mid-July. At this stage young crayfish are free-living miniatures of the adults. These young crayfish apparently molt once or twice more and are 8 to 10 mm TCL by the end of their first growing season.

Growth

Pacifastacus fortis, like all organisms with a chitinous exoskeleton, grows through a series of molts. Thus growth occurs intermittently in a stepwise pattern. The growing (molting) season of *P. fortis* (determined from the presence of soft or, more rarely, molting individuals in our samples) is from April to October. Adult males molt throughout the season, probably two to three times a year. Juveniles, especially in the first year, molt more frequently; however, molt data on young *P. fortis* are limited. Molting frequency of juvenile *P. leniusculus* is greater than that for adults (Mason 1975). Because additional energy is required for egg production and because about 9 months of maternal care is required for developing eggs and/or young, it is not surprising that most adult females molt only once each year—in July after the young have left. A second, lesser molting peak which occurs in the spring presumably includes sub-adults just reaching adult size (it was not possible to determine if soft individuals were in immediate premolt or postmolt stage), nonreproductive females, and females whose broods had been aborted.

Because molting is synchronous neither within a size group nor among size groups, estimates of growth increments for individual size groups during the summer from sequential length frequencies of unmarked crayfish are impossible. Mark/recapture or rearing experiments would provide needed data on this important aspect of the life history of *P. fortis*; however, several attempts to mark and recapture crayfish at Crystal Lake have been unsuccessful and difficulties in captive rearing need to be resolved.

Length-frequency histograms of *P. fortis* from Crystal Lake show a fairly even distribution among size groups with a slight tendency toward dominance by the largest (adult) class (Figure 5). Such size frequency distributions are characteris-

tic of stable, relatively long lived populations (Odum 1971). The increased frequency in the largest size group suggests that this more slowly growing adult group consists of two or more indistinguishable age classes.

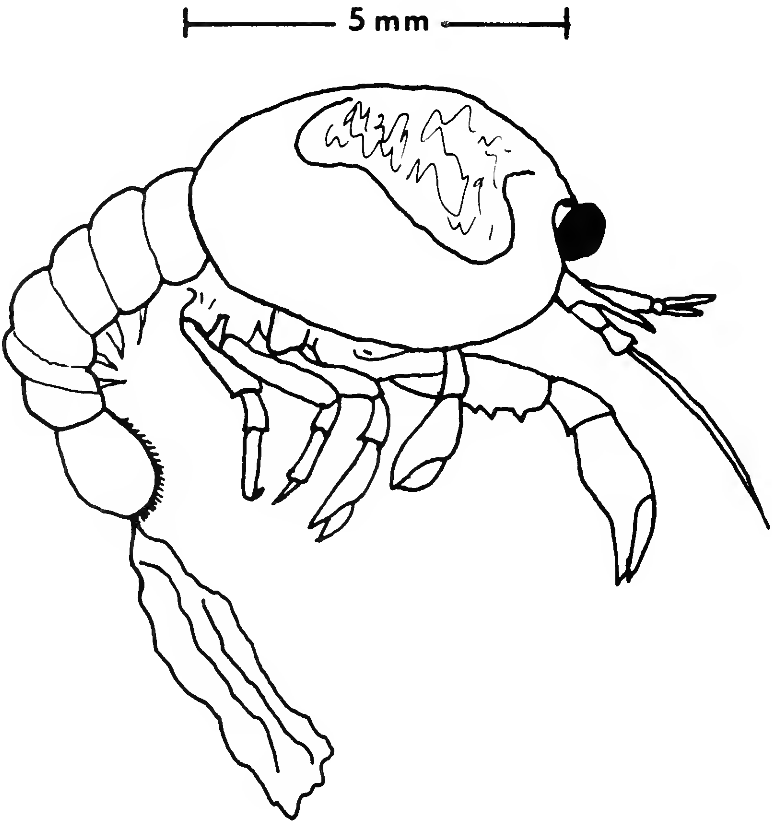

FIGURE 4. First instar *Pacifastacus fortis* a few hours after hatching.

Length-frequency analysis is further complicated by a size disparity between sexes in adult crayfish. Generally adult males average several millimetres longer than adult females (Figure 6); however, the four largest *P. fortis* measured have all been females. To date no data are available which directly explain this apparent anomaly, but we offer the following speculation. Molting is a critical time in the life of crayfishes and molting mortality is well known among decapod crustaceans. During our studies, we found several *P. fortis* that had died while molting. Individuals which molt successfully are especially vulnerable to injury and predation until their exoskeletons harden. Although there may be other mortality factors specific to females, molting and immediate post-molting mortality must be less for them than for males because of their lower molting frequency. Additionally female *P. fortis* are probably more secretive and less active than males during much of the year. Increased secretiveness and reduced

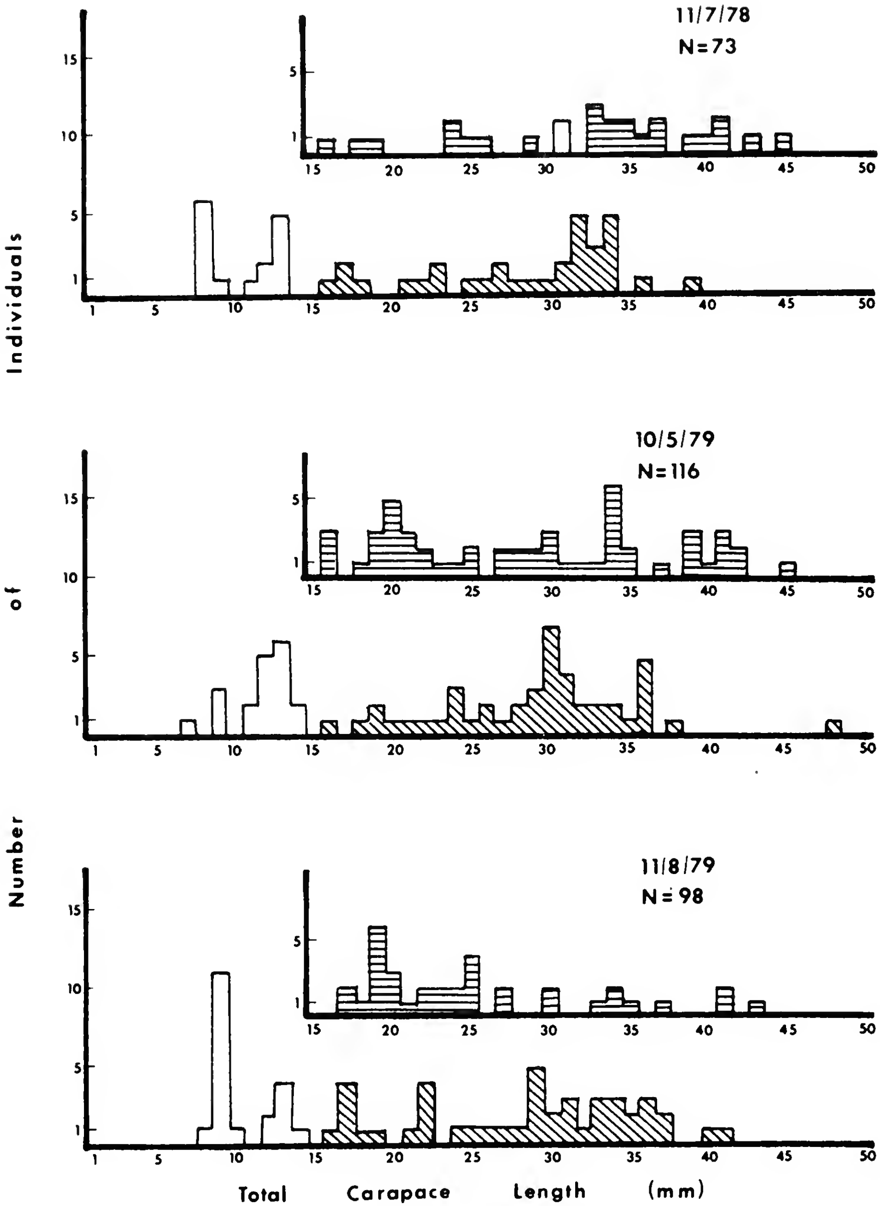

FIGURE 5. Length frequency of *Pacifactacus fortis* at Crystal Lake, Shasta County, California. ☐ unsexed; ▧ females; ▤ males.

activity of females while carrying eggs or young, well known in other species of *Pacifastacus* (Riegel 1959, Mason 1970), make them less vulnerable to predation than more active individuals. Since female *P. fortis* carry eggs or young from late

October into July, they should suffer fewer losses through predation or accident than adult males during the same time period.

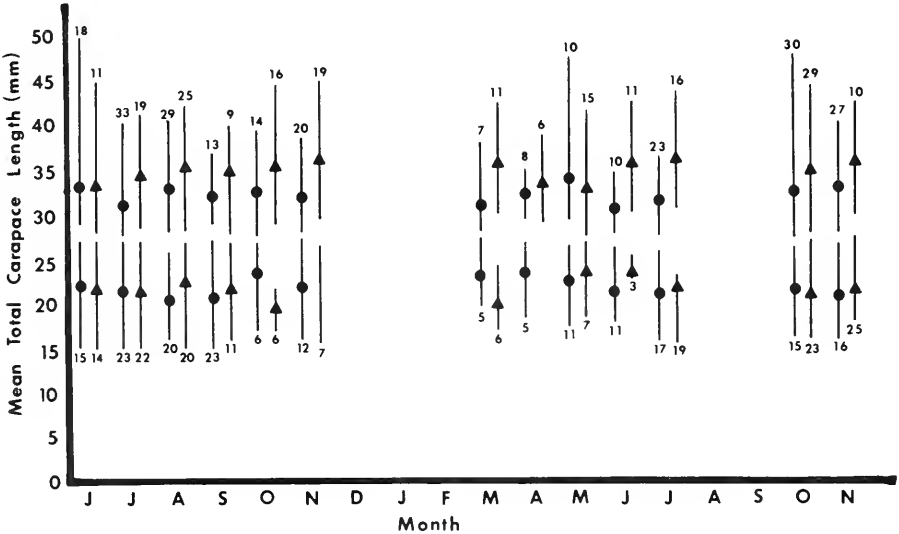

FIGURE 6. Mean length of *Pacifastacus fortis* at Crystal Lake, Shasta County. (The larger pairs are mature crayfish.) ▲ males; • females. Numbers indicate the sample size.

The greater average length of adult males compared to females in *P. fortis* may be due to more frequent molting of the former (therefore a more rapid growth rate). The occasional exceptionally large females are probably very old individuals. Males appear to have less likelihood of reaching similar advanced age because a higher molting frequency increases their molt related mortality and a greater period of activity increases the probability of their loss by predation or accident (including displacement to unfavorable habitat).

Length-frequency histograms of *P. fortis* measured in November 1978 and October 1979 (Figure 5), show four size groups among juveniles (7 to 27 mm TCL). Young-of-the-year crayfish have reached only 8 to 10 mm TCL by the end of their first growing season. Based on this very slow growth of the O+ crayfish, we tentatively conclude that the four size groups represent year classes (i.e., O+, 1+, 2+, 3+). Thus, *P. fortis* first becomes sexually mature during its fifth year. Other species of *Pacifastacus* typically mature in their second or third year (Miller 1960, Mason 1975), although female *P. leniusculus* in Lake Tahoe don't reach maturity until their fourth summer (Abrahamsson and Goldman 1970). No data are available for maturation of *Orconectes virilis* in western North America; however, in Michigan it becomes reproductively mature at 2 years (Momot 1967). Thus *P. fortis* takes significantly longer to reach reproductive maturity than do either of the crayfishes which have been introduced into its range.

Food

Very little is known about the diet of *P. fortis*. We have been unable to capture this species by using baited traps. Thus it may be a carnivore or browser rather than an omnivorous scavenger like *P. leniusculus,* which is readily lured to baited traps. Snails are an extremely abundant potential prey in Fall River and Hat Creek. Aquatic oligochaetes and insect larvae and nymphs are also common. *Pacifastacus fortis* maintained in aquaria have fed on both freshwater limpets and tubifex worms. Algae and sponges incrust the rocks of *P. fortis* habitat; however, rooted vegetation is uncommon. Freshwater sponges are a potential food source for a crayfish capable of scraping them from their substrate. Williamson (1979) has determined that an eastern crayfish, *Orconectes sp.,* does feed to a certain extent on freshwater sponges. Members of the subgenus *Hobbsastacus* all have a blade-like incisor region of the mandible which Bouchard (1977*b*) has speculated may be more efficient as a scraping mechanism facilitating the use of *Aufwuchs* as a food source. The subgenus *Pacifactacus,* to which *P. leniusculus* belongs, has a more generalized dentate-crenate incisor region (Bouchard 1977*b*). Plant material is an important component in the diet of *P. leniusculus* (Mason 1975; Flint and Goldman 1976).

The paucity of rooted aquatic vegetation in its habitat, its failure to be attracted to traps, and the morphology of its mouthparts suggest that *P. fortis* relies on predation, browsing of encrusting organisms, or detritivorism, either solely or in combination, for nutrition. Because knowledge of food habits will be very important in developing a viable management plan, studies to identify the dietary components of *P. fortis* need to be initiated.

Behavior

Pacifastacus fortis is nocturnal and remains hidden under rocks during the day. Several *P. fortis* are frequently found beneath a single rock, leading to speculation of gregarious behavior (Bouchard 1977*a*, Daniels 1980). Our field observations suggest that rather than being gregarious *P. fortis* is merely tolerant of the proximity of other crayfish if space is available. Solitary crayfish are often found and no more than one *P. fortis* has yet been found beneath rocks of 20 cm or less in diameter. Very preliminary data suggest that only one ovigerous female *P. fortis* would be found beneath a given rock even though several juveniles and males would coinhabit. This observation requires further study. If brooding females exclude other females from their shelters, the population size may be limited by the number of satisfactory shelters available.

Pacifastacus fortis does not appear to be as aggressive as *P. leniusculus* and many other crayfish species. Only infrequently does it exhibit the classic crayfish defensive posture of raised chelae. Typically when *P. fortis* is exposed by lifting the rock under which it is hiding the crayfish remains motionless or attempts to burrow deeper into the sand. Occasionally it will crawl away to seek shelter beneath a nearby rock and, even less commonly, will escape by several quick flexures of the abdomen. In the flowing water of their spring-fed habitat such reluctance to move may reduce downstream displacement and thus be adaptive, particularly if satisfactory shelters are at a premium.

Biological Associates

Pacifastacus fortis is usually infested by commensal oligochaetes (Branchiobdellidae). These leech-like worms which attach to the crayfish exoskeleton and gills by a posterior sucker are often very abundant. Branchiobdellids are common epizoids on most freshwater decapods (Holt 1968).

Another group of crustacean commensals found on the carapace of *P. fortis* belongs to the ostracod family Entocytheridae. Hart and Hart (1974) reported that at least three species including *Uncinocythere caudata* (Kozloff), *U. neglecta* (Westervelt and Kozloff), and *U. ericksoni* (Kozloff) have been identified from *P. fortis*.

Exotic Crayfish

Two exotic crayfish species are now established within the historical range of *P. fortis*. *Orconectes virilis*, a native of the midwestern states, occurs in Pit River downstream from Pit River Falls. *Pacifastacus leniusculus* is native to the Pacific northwest, but has been widely introduced throughout northern and central California (Riegel 1959). Within the range of *P. fortis*, established populations of *P. leniusculus* occur in Burney Creek and Baum Lake. Recently, *P. leniusculus* were taken in Crystal Lake, Hat Creek, and Fall River downstream from Glenburn. We do not know when these exotic species were introduced to the midreaches of Pit River, but it was apparently after Riegel's (1959) study of crayfish distribution in California. Introduction of both species probably resulted from angling activities. Don Estey (Fish Hatchery Manager, Calif. Dept. Fish and Game, pers. commun.) reports that anglers were using crayfish for bait in Lake Britton and Pit River during the early 1960's. There have also been reports of their use by bass anglers in Big Lake of the Fall River system.

Orconectes virilis is a relatively aggressive species. It is known to have displaced native crayfish species in some areas where it has been introduced (Schwartz *et al.* 1963, Bouchard 1977*b*).

Pacifastacus leniusculus is also an aggressive species and is believed to have contributed to the extinction of the endemic *P. nigrescens* in Alameda and Santa Clara counties (Bouchard 1977*a*).

Pacifastacus leniusculus is larger and more fecund than *P. fortis*, often exceeding 50 mm TCL and females typically produce 100 to 400 relatively small eggs (Miller 1960). By contrast, *P. fortis* seldom reaches 50 mm TCL and females produce fewer than about 70 relatively large eggs. Young *P. leniusculus* are liberated earlier than are young *P. fortis*. In June 1978, while *P. fortis* were still carrying young (and would continue to do so for another 4 to 6 weeks), *P. leniusculus* young in Baum Lake were already free living.

Another concern is possible hybridization of *P. leniusculus* with *P. fortis*. To date no confirmed hybrids have been observed; however, the opportunity for such hybridization has not been possible until relatively recently. Bouchard (1977*a* and pers. commun.) did not find *P. leniusculus* in Baum Lake in 1975, but as noted above, a moderate population of this species is now established there. Relatively few *P. fortis* presently occur in Baum Lake.

Although no life history data are available for northern California populations of *O. virilis*, data from eastern United States populations suggest that they grow more rapidly than *P. fortis*. Momot (1967) reported that *O. virilis* 6 mm TCL when

they left the female were 19 to 21 mm TCL by late October and early November. *Orconectes virilis* reached reproductive maturity during its second summer (Momot 1967, Momot and Gowing 1977). This species is also more fecund than *P. fortis*. Momot (1967) reported that mean egg count of ovigerous *O. virilis* to be 94. A similar fecundity (67 to 145 eggs) was reported by Momot and Gowing (1977).

Thus, within its restricted range *P. fortis* is now threatened by two exotic crayfishes, both of which are faster growing, faster maturing, more fecund, and more aggressive than it is. Both exotic species have been introduced to the area relatively recently and are presently expanding their range within the mid-reaches of the Pit River system. Only time will tell if this expansion is at the expense of the native crayfish; however, our outlook at present is pessimistic.

CONCLUSIONS

Preliminary data suggest that *P. fortis* is a slow-maturing, relatively long-lived species, with low fecundity; it is highly adapted to living in cool, clear, spring-fed habitats where the predominant food items available are benthic invertebrates and *Aufwuchs*.

Threats to the continued existence of *P. fortis* include habitat alteration, exotic predators and competitors, increasing human population in the area, and harvest for human consumption. These threats are not mutually exclusive and in some cases may be considered cumulative.

ACKNOWLEDGMENTS

D. Baltz, P. Brouha, B. Bryan, J. Dentler, M. Feeley, L. Martin, P. Moyle, S. Nicola, and M. Rode assisted in the field studies. R. W. Bouchard and H. H. Hobbs, Jr. kindly reviewed the manuscript and provided many useful comments. Final drafting of the figures was done by N. Dubbs. Support for this study was provided by U. S. Forest Service contract No. 53 9A28 8 2589 and U. S. Fish and Wildlife Service Endangered Species Act grant-in-aid project, California E-F-2, E-F-3, and E-F-4.

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Calif. Fish and Game 68(4): 213-223 1982

MARINE MAMMALS IN MONTEREY BAY, CALIFORNIA, DURING THE YEARS 1950–1955 [1]

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Over about a 5-year period, 180 sightings of 12 marine mammal species and three unidentified mammal categories were made during 239 weekly sea trips. Most frequently sighted were the Pacific white-sided dolphin and Dall's porpoise. Mean herd sizes were 13.90 and 5.98 animals, respectively. The white-sided dolphin was absent from early May to early September; the majority of sightings occurred from December to March. Dall's porpoise was seen around the calendar, but more frequently during the last half of the year. Killer, short-finned pilot, and sperm whales were noted only in that same period. The majority of gray whale sightings were correlated with their winter migrations, but a few stragglers were seen as late as July. No seasonality is evident from the humpback whale sightings. Northern fur seals were observed only from January to June. Two northern elephant seals and one sea otter were noted.

INTRODUCTION

During the early 1950's I took part in a long-term hydrobiological study of Monterey Bay, conducted by personnel of Stanford University, Hopkins Marine Station, Pacific Grove, California. Aside from the scheduled work, sightings of marine mammals were routinely noted. Because historical time-series data can contribute to present perspectives of marine mammal populations in California coastal waters, this paper presents a summarized analysis of notes recently extracted from our old station records and anecdotal comments.

METHODS AND PROCEDURES

Over 62 months, 239 1-day trips were made at approximately weekly intervals. On each trip, two stations were occupied. One station was in the vicinity of the bell buoy, about 1 km north of the Monterey Harbor breakwater. The other, a deep-water station, was approximately 11 km southwest of Pt. Pinos (Figure 1). The round trip between the two stations in the 12-m motor launch, TAGE, covered about 33 km. The outbound course traversed shallow water to a position over the trough of the Monterey Submarine Canyon, a depth of about 1,829 m. On this "deep-water station", temperatures, water samples, and plankton or micronekton tows were taken at various depths, and 3 to 5 h were spent either drifting or traveling slowly within about a 2-km radius. The return trip tended in a more easterly direction, and the stop at the bell buoy station was limited to about 25–30 min. The starting times of the trips fluctuated with the seasons, normally beginning just at daybreak and usually ending by 1500–1600 h.

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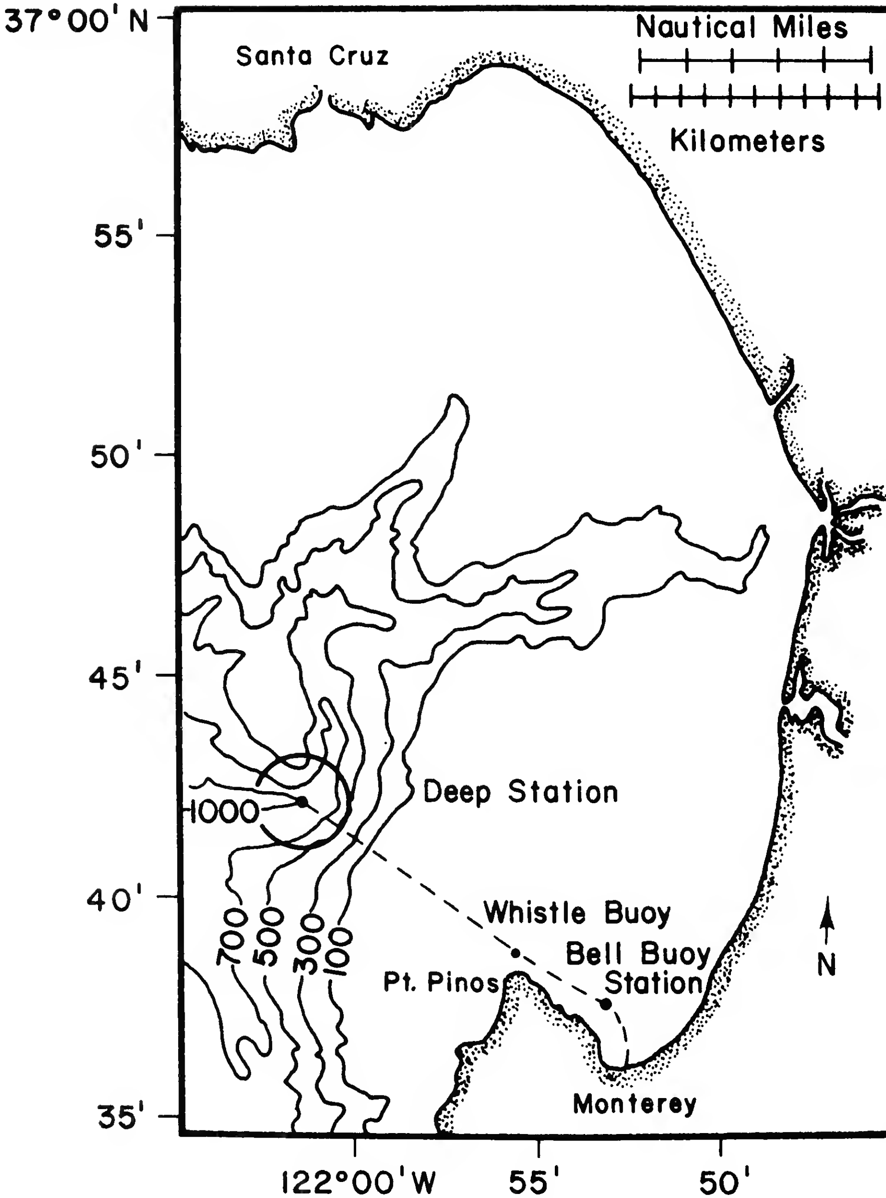

FIGURE 1. Course of the TAGE trips in Monterey Bay. The circle indicates the approximate area of movement and drift while occupying the deep station. Depth contours are indicated in fathoms.

The TAGE normally carried three people, two scientists and a vessel operator. All hands contributed to the marine mammal sightings, but the effort was not constant and was affected by sea conditions, weather, and the work priorities.

The intensity of effort was also constrained by individual interests and seaworthiness of various crew members. While during the course of the program some 18 persons functioned as crew members, two people, Thomas Fast (143 trips) and I (160 trips) made the majority of the observations. Most of the identifications and number estimates were verified by at least two crew members.

No codes or special forms were used in recording these data. The observations were simply written as "notes" on the hydrographic station records, and I have extracted these data from the original forms, or in the cases of the earliest records from handwritten summaries. The content of the notes varied from abbreviated notations of the species and time of the sightings, usually with estimated numbers, to occasional lengthy comments on unusual behavior patterns or events. While in some cases one sighting may have led to another, for the purposes of this report each log entry is considered a separate sighting.

In many cases, the animals were unidentified or the determination was considered doubtful. In working up these data, I have relegated all such observations to the "unidentified" categories. Frequently the estimates of herd or aggregation sizes were given as a number followed by a ± approximation: here I have scored the point estimate. At other times spread estimates (e.g. 10–15) were listed; in these situations I have either used the midpoint or alternately rounded to the low or high integer. The nomenclature used here for smaller cetaceans is that recommended by the International Whaling Commission (1976).

RESULTS AND DISCUSSION

During the course of the TAGE "deep-water station" cruises we logged 180 marine mammal sightings comprised of 12 species and three "unidentified categories" (Table 1).

TABLE 1. Marine Mammals Noted on Monterey Bay TAGE Trips, 1950–1955.

	1950	*1951*	*1952*	*1953*	*1954*	*1955*	*Total*
Number of sea trips	7	51	51	42	46	42	239
Total number of marine mammal observations	7	39	44	34	33	23	180
Specific observations:							
Dall's porpoise							
Phocoenoides dalli	4	11	13	8	10	7	53
Pacific white-sided dolphin							
Lagenoryhnchus obliquidens	2	9	10	8	6	5	40
Unidentified porpoise or dolphin	1	5	2	2	3	4	17
Sperm whale							
Physeter catodon		1					1
Killer whale							
Orcinus orca		1	1	1	1		4
Short-finned pilot whale							
Globicephala macrorhynchus			3				3
Gray whale							
Eschrichtius robustus			3	3	2	4	12
Fin/sei whale							
Balaenoptera spp.					3		3
Humpback whale							
Megaptera novaeangliae		1	2	4	1	2	10
Unidentified whale		8	3	2	5		18
California or steller sea lion							
Zalophus californianus or							
Eumetopias jubatus			2	1	1		4

Northern fur seal						
Callorhinus ursinus	1	3	4	1	1	10
Northern elephant seal						
Mirounga angustirostris	1		1			2
Unidentified pinniped		2				2
Sea otter						
Enhydra lutris	· 1					1

The small odontocetes, Dall's porpoise, *Phocoenoides dalli,* (53 sightings) and the Pacific white-sided dolphin, *Lagenorhynchus obliquidens,* (40 sightings) were by far the most frequently seen, comprising over 50% of all observations. An additional 17 sightings of unidentified small odontocetes were also made, most of which were probably these two forms.

These animals generally travel in small herds. Estimates of their numbers were made for 31 aggregations of white-sided dolphins and 40 of Dall's porpoise (Figure 2). The larger aggregations of both species tended to be seen after a long period of apparent absence in Monterey Bay. The mean herd size of *L. obliquidens* was larger (about 14) than those of *P. dalli* (about 6); thus, the first species apparently is the more abundant. Very probably, in some cases we were seeing the same groups of animals on the same or different trips. This seemed particularly likely for Dall's porpoise. For example, a herd of six animals tended to be seen at relatively frequent intervals at about the same location.

Differences in behavior may have affected the frequency of sightings of the two forms, for unless occupied in feeding, the white-sided dolphins would approach the TAGE from long distances and ride in the bow and stern wakes for considerable lengths of time, usually with a spectacular show of acrobatics that in one case landed an animal on the vessel's foredeck (Dearborn 1968).

Dall's porpoise, on the other hand, were not so conspicuous. They rarely rode the bow but frequently would briefly run parallel with the boat's course or rapidly cut across the bow or the stern wake. Morejohn's observations in 1979

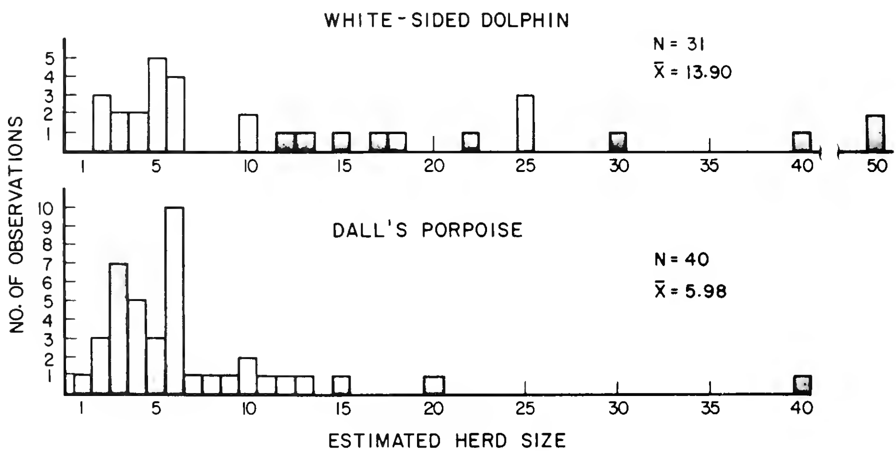

FIGURE 2. Frequency distribution of herd size estimations for the Pacific white-sided dolphin and Dall's porpoise.

indicated that *P. dalli* will not bow ride such slow vessels as the TAGE (8–10 kts), but are strongly attracted to boats cruising at speeds of 14–16 kts or faster. When encountered, these animals swam extremely rapidly and low in the water, making slashing respiratory rises to the surface and were normally barely visible while breathing. Their respiratory sounds were explosively loud, and these sounds frequently cued us to their presence. Leaping behavior was rare and subdued.

Location data were recorded for *P. dalli* and *L. obliquidens* in 36 and 21 cases, respectively. Fifty percent of the Dall's porpoise locations were observed from the whistle buoy to the canyon slope (Figure 1) and the 100 fm curve seemed to be a favorite *P. dalli* location. In contrast, only about 24% of the white-sided dolphin sightings were made in this area and the majority were over the canyon's axis.

Occasionally herds of white-sided dolphins would stay in the immediate vicinity of the vessel for several hours while we drifted on the deep station. In view of the now well-known tuna-dolphin bond in the eastern tropical Pacific (Perrin 1968), an observation made on one such occasion is of special interest. On 9 October 1951, Rolf Bolin and Howard Feder noted that a large herd of about 50 *L. obliquidens* appeared to be chasing a school of albacore (*Thunnus alalunga*).

Because of the high probability of redundant sightings, the behavioral factors, and the constraints on consistent searching effort, the TAGE records do not lend themselves to quantifiable abundance estimates. On a "present or absent" basis, however, they do provide a baseline for seasonal comparisons. These data relative to the monthly number of TAGE trips are listed in Table 2.

The white-sided dolphin showed a striking seasonality. Over the period of the study, this animal was not seen from early May to early September, and the majority of the sightings (71%) were clustered in the December to March period, suggesting that this species is primarily a fall-winter resident in Monterey Bay. Contrariwise, Dall's porpoise was noted at least once in every month of the year. This pattern is consistent with observations made elsewhere on the Pacific Coast (Morejohn 1979). The sightings, however, are sparse for January–February and tended to be more frequent (64%) during the second half of the year.

Results for the two dominant forms can be compared with more recent observations. As might be expected, the seasonality and habits of *L. obliquidens* in Monterey Bay appears to be somewhat different from those off southern California. Norris and Prescott (1961) reported that this species is present only in the nearshore Channel Islands area in the cool-water winter-spring period, then moving offshore during the summer-fall. They suggest that the movements of white-sided dolphins are related to seasonal variations in their food supply since the market squid, *Loligo opalescens*, becomes abundant nearshore during late fall and winter months. In Monterey Bay, however, absence of *L. obliquidens* correlates closely with the upwelling period, when sea water temperatures at our deep station were generally the coldest (Barham 1956). This period occurs during the months of the major squid landings in Monterey (Calif. Dept. Fish Game, Fish Bulletins, Fish Landing Statistics shows that about 70% of the *L. opalescens* catch during the 1950–55 period were taken during April to August). On the other hand, our data closely fit Brownell's (1964) observations

TABLE 2. The Seasonality of the More Frequently Sighted Marine Mammals in Monterey Bay. (Indicated are the number of TAGE trips on a monthly basis during which these species were noted at least once.)

Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
					Number of TAGE Trips							
1950											3	4
51	5	4	4	4	5	4	4	5	4	5	4	3
52	5	3	4	5	4	4	5	4	5	4	4	4
53	4	3	2	4	5	4	5	4	3	2	3	3
54	4	5	3	3	4	5	3	4	4	3	3	4
55	3	4	4	3	4	3	4	4	4	4	3	2
					White-sided Dolphins							
1950											1	1
51	0	3	2	0	0	0	0	0	0	1	0	2
52	2	1	0	2	0	0	0	0	0	1	1	2
53	2	0	1	1	0	0	0	0	0	0	0	0
54	2	0	1	0	0	0	0	0	2	1	0	0
55	1	1	1	0	1	0	0	0	0	1	0	0
					Dall's Porpoise							
1950											1	2
51	1	0	1	2	0	1	0	1	0	1	0	2
52	0	0	2	0	0	1	0	1	3	1	3	0
53	0	0	1	0	0	1	2	2	1	0	0	0
54	1	0	0	1	1	0	1	3	0	1	0	1
55	0	1	0	0	1	1	0	0	1	2	0	0

Gray Whales

1950											0	0
51	0	0	0	0	0	0	0	0	0	0	0	0
52	1	1	0	0	0	0	1	0	0	0	0	0
53	2	0	0	0	1	0	0	0	0	0	0	0
54	1	0	0	0	0	0	0	0	0	0	0	1
55	1	1	1	1	0	0	0	0	0	0	0	0

Humpback Whales

1950											0	0
51	0	0	1	0	0	0	0	0	0	0	0	0
52	0	0	0	0	1	0	0	0	0	0	1	0
53	2	0	0	0	0	1	0	0	0	1	0	0
54	0	0	0	0	0	0	1	0	0	0	0	0
55	0	0	0	1	0	0	0	0	0	1	0	0

Fur Seals

1950											0	0
51	0	0	0	0	1	0	0	0	0	0	0	0
52	0	0	2	1	0	0	0	0	0	0	0	0
53	1	1	0	2	0	0	0	0	0	0	0	0
54	1	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	1	0	0	0	0	0	0

that off central California the white-sided dolphin population is found offshore during the summer. Most of the *L. obliquidens* herds sighted by Brownell were feeding on northern anchovy, *Engraulis mordax*, and Brownell suggests that the dolphin's seasonal movements are related to the availability of the anchovies. The offshore movements of *L. obliquidens* are probably restricted to the California Current system, for Fiscus and Niggol (1965) report that they are concentrated between the 100 fm curve and about 60 miles offshore. These workers also noted a close association between *L. obliquidens* herds and anchovy schools.

Regarding herd size, observations made farther to sea indicate that the white-sided dolphin travels in large groups and frequently in company with other cetacean species, in contrast to the relatively small, pure resident herds we encountered in Monterey Bay. For example, Brownell's (1964) estimates of size for seven herds have a mean of about 36, and, based on 135 sightings, Fiscus and Niggol (1965) saw herds as large as 500 but with groupings of 20–100 being more common. Walker (1975) also reports larger herds in southern California waters, with one group being as large as 1,000 animals.

Our results for *Phocoenoides dalli* can also be compared with more recent observations. Loeb (1972) made 96 sightings during 46 trips in Monterey Bay. She had the specific objective of studying the species over a 22-month period in the early 1970's. As with our results, Dall's porpoise were present in every month of the year in groups of 2 to 50 animals. (I have computed the mean herd size from her data as 5.33, compared to our 5.98.) Unlike for *L. obliquidens,* the small herd size seems to hold for Dall's porpoise along most of the Pacific coast. Fiscus and Niggol (1965) give an average size of 4–5 for 251 sightings, and, by taking the mid-point of two of Brownell's (1964) 11 herd size estimates, the mean herd size from his data is 6.64. At the southern extreme of the Dall's porpoise range, where they are regular winter visitors in the Channel Island area (Norris and Prescott 1961; Brownell 1964; Walker 1975), herd size appears to be larger; Norris and Prescott's (1961) data for 52 sightings have a mean of 15.21.

Three other species of small odontocetes that we did not positively identify are known to inhabit Monterey Bay (Norris and Prescott 1961; Fiscus and Niggol 1965). The notes indicate that while on several occasions we thought that we had sighted harbor porpoise, *Phocoena phocoena,* we were never certain of the identification. The only close encounter we had with this small, surreptitious animal was with an old male that stranded at Stillwater Cove near Pebble Beach on 20 May 1955 (Boolootian 1957). Thomas Fast and I tried to get this animal to swim back to sea. Failing in that, we took him back to Hopkins Marine Station and placed him in the largest cement tank available in the basement wet lab. We vainly tried to feed him, but he died within a day. According to Fiscus and Niggol (1965), and Leatherwood and Walker (1979), it would seem that we should also have sighted the northern right whale dolphin, *Lissodelphis borealis.* This slim, dorsal-finless form should be easily identified at close range, although it could be confused with either Dall's porpoise or running and jumping sea lions at a distance.

Another "missing species" was Risso's dolphin, *Grampus griseus.* At one time this large, robust form was considered abundant in Monterey Bay (Leatherwood *et al.* 1980), and it would be unlikely that this strikingly colored and singularly

behaved animal would be confused with other species. The period of our observations coincided with a relatively cool-water phase which may have restricted *G. griseus* to more southerly latitudes, or we may just not have been far enough out to sea to encounter Risso's dolphins. These conditions may also explain our failure to sight the common dolphin, *Delphinus delphis.*

In contrast to sightings of the dolphins and porpoise, observations of larger odontocetes were relatively sparse (Table 1). For example, killer whales, *Orcinus orca,* were noted only once a year for the period 1951–54, and short-finned pilot whales, *Globicephala macrorhynchus,* were only positively identified on three occasions, all in one year (1952). The only sperm whale, *Physeter catodon,* was seen on 11 July 1951, about 6.5 km off Pt. Pinos. The identification is certain, since the TAGE approached within 15 m of the animal. Seasonally, all of these observations were in the last half of the year. Interestingly, the killer whale sightings are seasonally out of phase with the major migrational periods of the gray whales, *Eschrichtius robustus,* a known prey of *O. orca* in the Monterey Bay area (Morejohn 1968; Baldridge 1972).

Aside from the TAGE deep-water station trips other chance observations of these species are of interest. For example, the short-finned pilot whale may have been more common on the northern side of the bay than at the deep-water station. Several observations were made in the 1950's of these animals on the California Cooperative Oceanic Fisheries Investigation (CalCOFI) weekly TAGE trips that crossed over to the Santa Cruz side of the bay.

On several occasions at Hopkins Marine Station in Pacific Grove, we also saw small groups of killer whales patrolling the offshore rocks and harassing California sea lions, *Zalophus californianus.* I once saw a killer whale leap and take a low-flying cormorant (*Phalacrocorax* spp.) in mid-air.

Regarding mysticete whales, most were seen fleetingly and at considerable distances, and only 25 of the total of 45 sightings were identified positively (Table 1). The six sightings of *Eschrichtius robustus* in December and January were gray whales very likely on their southward migration, and the four animals seen in late April were most likely northbound (Table 1). The two unseasonable sightings in late May and early July were probably of migratory stragglers that linger along the Pacific Coast rather than returning to their Arctic feeding grounds (Rice and Wolman 1971; Patten and Samaras 1977).

Humpback whales, *Megaptera novaeangliae,* were positively identified about as frequently as gray whales (Table 2). These sightings were scattered throughout the year with no apparent seasonal trends (Table 1). The presence of humpback whales in Monterey Bay during the summer months is consistent with their known movements. Our sightings, however, in the winter months would seem unseasonal relative to the generality that this species congregates in tropical and subtropical waters during the winter, rarely moving northward along the Pacific coast as far as southern California (Rice 1974).

The fin/sei whale (*Balaenoptera* sp.) observations were all made in the last 2 weeks of November 1954, and all were seen at about the same location, about 1 km seaward of Pt. Pinos.

Concerning pinnipeds, all 10 of the sightings of northern fur seals, *Callorhinus ursinus,* were made at the deep station, and all appeared to be females or young

males. Most were seen drifting at the surface with one pectoral fin held high out of the water. All of these observations were made during the first half of the year (Table 2), a period that coincides with the known pelagic migrations of northern fur seals (Fiscus and Kajimura 1967). These authors indicate that the deep station was at the shoreward fringe of the major concentration of *C. ursinus.*

One of the two observations of the northern elephant seal (*Mirounga angustirostris*) was made on a foggy day (1 September 1953). At the edge of the mist a large form rose up out of the water and held its position, not unlike a swimmer treading water. We cut the boat's engine and from upwind drifted within arms length of the animal whose head was about at the level of the taffrail, about 1 m above the sea surface. It was a female with an opaque film over her eyes. She seemed to sense, rather than see us, sank down in the water and disappeared. While I have no desire to destroy a local myth, based on this observation it would seem that elephant seals offer a logical explanation for the "Old Man of the Sea" phenomenon, a tale told by Monterey fishermen of an eerie, man-like apparition that rises up out of the sea only to disappear as a vessel approaches (Steinbeck and Ricketts 1941, pp. 30–31).

The few sea lion observations recorded, *Zalophus californianus* or *Eumetopias jubatus,* (Table 1) were all made at considerable distances from land, as sea conditions usually kept us from running close enough to the rocky Pacific Grove headlands to attempt routine counts of near-shore pinnipeds.

Even though it seems rather far at sea for them, a sea otter, *Enhydra lutris,* was noted on two occasions on one deep station trip (24 April 1951). This was several years before sea otters had migrated up the coast as far as the Yankee Point-Point Lobos area.

Two other sources of marine mammal sighting information in the Monterey Bay area exist that have not been discussed here. From 1969 to 1971, Alan Baldridge compiled lists of sighting information in Hopkins Marine Station's Annual Reports of CalCOFI hydrographic data. Part of those data were shore records from various sources and part were made during the TAGE hydrographic trips across the bay. In addition, J. Victor Morejohn of the Moss Landing Marine Laboratory has gathered marine mammal data over a long period (pers. commun.). His information on the natural history of Dall's porpoise was recently published (1979).

ACKNOWLEDGMENTS

The deep-station work was sponsored by the Office of Naval Research and the National Science Foundation. The work was under the direction of the late R. L. Bolin, who wisely instigated the policy of making marine mammal observations. In large part, this phase of the program was furthered by T. Fast. Other Hopkins Marine Station faculty and students who made major contributions to the marine mammal observations were: D. Abbott, C. O'Connell, H. Feder, B. Chaffey, M. Jollie, L. Dreis McCann and L. Greenfield. At various times, four TAGE skippers aided the work; G. DeVlamick, D. Owens, L. Lewis, and J. Balesteri. The TAGE data records have been curated by D. Abbott, Associate Director of Hopkins Marine Station, who kindly made them available to me. W.

Walker and W. Perrin have made helpful suggestions, and Perrin has read a draft of this manuscript, which has been written with support from the National Marine Fisheries Service, Southwest Fisheries Center laboratory.

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FOOD HABITS OF THE GRAY SMOOTHHOUND, *MUSTELUS CALIFORNICUS,* THE BROWN SMOOTHHOUND, *MUSTELUS HENLEI,* THE SHOVELNOSE GUITARFISH, *RHINOBATOS PRODUCTUS,* AND THE BAT RAY, *MYLIOBATIS CALIFORNICA,* IN ELKHORN SLOUGH, CALIFORNIA [1]

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The food habits of four elasmobranch fishes, collected from October 1971, through December 1972, were examined. The study took place in Elkhorn Slough, a shallow estuary near Moss Landing, California. Gray smoothhound sharks fed primarily on crabs in Elkhorn Slough; the yellow shore crab, *Hemigrapsus oregonensis,* was the most important food item for all sizes of gray smoothhounds, but three species of *Cancer* crabs were also important food items. Brown smoothhound sharks fed mostly on crustaceans, with *H. oregonensis, Cancer gracilis,* and *Cancer productus* being the most important crustaceans; fishes were important food items for larger sharks. Shovelnose guitarfish fed mostly on crustaceans, with *H. oregonensis* being the most important food item in all sizes of this guitarfish. Bat rays fed mostly on clams and the echiuroid worm, *Urechis caupo.* Small bat rays fed primarily on small clams, but there was a transition from clams as the major food source to *U. caupo* in bat rays greater than 80 cm disc width.

INTRODUCTION

Although several species of elasmobranch fishes are common in inshore communities along the California Coast, the food habits of many species are unknown. Moreover, the role that lagoons and estuaries play in the life history requirements of most inshore elasmobranches is unknown. Inasmuch as estuarine habitats such as Elkhorn Slough are frequently developed for industrial and recreational purposes, more information is needed about resource utilization of elasmobranchs in estuarine habitat.

The purpose of this paper is to present a descriptive account of the food habits of the gray smoothhound shark, *Mustelus californicus,* the brown smoothhound shark, *Mustelus henlei,* the shovelnose guitarfish, *Rhinobatos productus,* and the bat ray, *Myliobatis californica.* These four species of elasmobranch fishes are very common along much of the California Coast and all are common in Elkhorn Slough. Information pertaining to the food habits of these species is fragmentary. Most information available on the food habits of the four species in Elkhorn Slough comes from general observations made at shark derbies (Herald and Dempster 1952; Herald 1953; Herald *et al.* 1960). Additional information is available on the food habits of the brown smoothhound and bat ray in other areas (Russo 1975; Karl and Obrebski 1976).

MATERIALS AND METHODS

Elasmobranchs were collected from Elkhorn Slough, located between Monte-

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rey and Santa Cruz, California. Elkhorn Slough consists of about 1000 ha of submerged marine areas, tidal flats, and salt marsh. Although Elkhorn Slough sometimes resembles an estuary, relatively little fresh water enters the slough except during the fall-winter rainy season. Throughout most of the year Elkhorn Slough resembles a lagoon and the salinity is near that of sea water (Browning 1972).

Most elasmobranchs were collected in an area 2.4 km from the mouth of Elkhorn Slough (Figure 1). These fishes were captured from October 1971, through December 1972, with 90-m nylon gill nets divided equally among three mesh sizes: 10.2-, 15.2-, and 22.9-cm stretch mesh. To avoid capturing large numbers of bony fishes, no mesh size smaller than 10.2-cm stretch was used. Nets were set once a week if possible, 1 or 2 hr before sunset and picked up the following morning.

Elasmobranchs were also obtained from two shark derbies held in Elkhorn Slough during June 1972, in which specimens were captured during daylight hours by hook-and-line.

All elasmobranchs were measured and sexed. Total length (TL) was determined for all specimens except bat rays, for which disc width (DW) was taken. The stomach of each elasmobranch was removed, labeled, and placed separately in 10% formalin. Later, stomach contents were identified to the lowest possible taxon that the condition of the material permitted, and the number and volume of each species of food item was recorded. Bait used to capture elasmobranchs during shark derbies was not included in analyses of data. To evaluate intraspecific variation in food habits, elasmobranch fishes were separated into size classes and the data analyzed accordingly.

The Index of Relative Importance (IRI), which combines numerical, volumetric, and frequency of occurrence measurements of each prey item into one value, was used to rank the importance of each food item in the diet (Pinkas, Oliphant, and Iverson 1971). The combination of percentages, (number + volume) × (frequency), equals the Index of Relative Importance. The value of the IRI ranges from zero, when all values are zero, to 20,000 when all three indices are 100%.

Evaluations of seasonal changes in food habits were not possible because gray smoothhounds, brown smoothhounds, and shovelnose guitarfish were not present in the slough throughout the year; and, although bat rays were captured every month, various size classes were poorly represented during some seasons. The food habits of elasmobranchs for a particular size class, however, did not vary noticeably during the time they were captured in the slough. Thus, the data presented for each size class represent the combined food habits of males and females throughout the time individuals were captured in Elkhorn Slough.

RESULTS AND DISCUSSION

Species Accounts

Mustelus californicus

Fifty-two gray smoothhound sharks (60 to 120 cm TL) were captured in Elkhorn Slough; forty-nine (94%) specimens contained food items. Gray smoothhounds fed primarily on crabs in Elkhorn Slough (Table 1). Only four

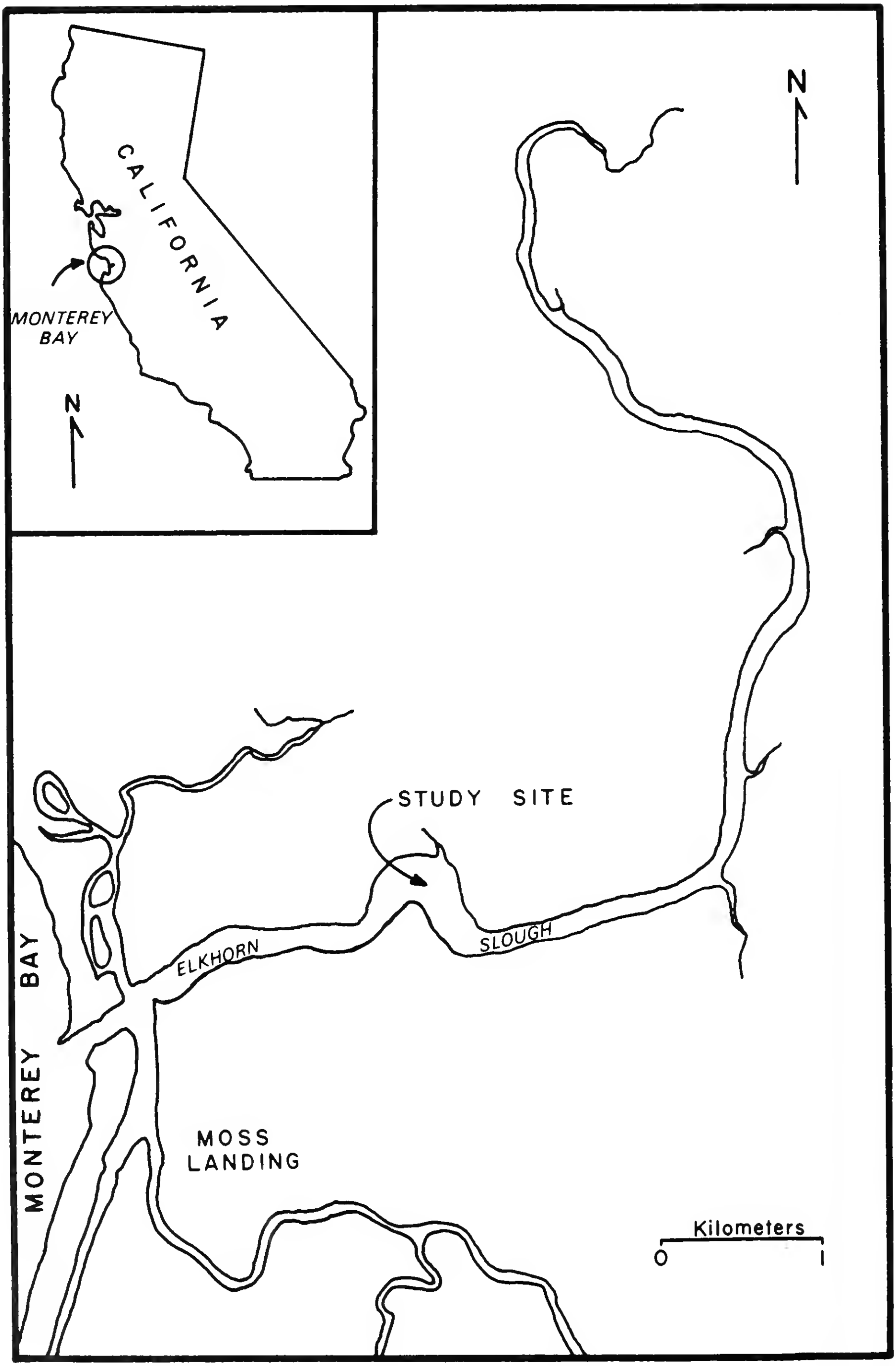

FIGURE 1. Map of Elkhorn Slough showing study site.

TABLE 1. Percent Number (%N), Percent Volume (%V), Percent Frequency of Occurrence (%F.O.), and Index of Relative Importance (IRI) of Food Items in the Diet of Gray Smoothhounds, 60 to 120 Cm Total Length, Captured in Elkhorn Slough, Monterey Bay, California

	Total length (cm)											
	60–79.9 (14) *				80–99.9 (24) *				100–119.9 (11) *			
Food item	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*
Echiuroidea												
Urechis caupo	–	–	–	–	1.6	2.1	8.3	31	–	–	–	–
Crustacea (Total)	100	100	100	20000	97.6	89.5	91.7	17157	98.8	99.9	100	19870
Crangon sp.	–	–	–	–	–	–	–	–	1.2	.1	9.1	12
Cancer antennarius	.9	4.2	7.1	36	.8	.8	4.2	7	8.4	15.2	54.6	1289
Cancer gracilis	7.1	14.7	42.9	935	12.1	18.5	41.7	1276	6.0	5.3	36.4	411
Cancer productus	3.5	9.4	28.6	369	1.6	4.3	8.3	49	22.9	54.4	63.6	4916
Hemigrapsus oregonensis	86.4	56.3	71.4	10189	82.3	51.3	87.5	11690	59.0	21.6	72.7	5860
Unidentified crab parts	–	12.6	21.4	270	–	14.4	20.8	300	–	2.8	9.1	25
Blepharipoda occidentalis	.9	1.7	7.1	18	–	–	–	–	–	–	–	–
Callianassa gigas	.9	1.1	7.1	14	.8	.2	4.2	4	1.2	.6	9.1	16
Pisces (Total)	–	–	–	–	.8	8.4	4.2	39	1.2	.1	9.1	12
Clupea harengus pallasi	–	–	–	–	.8	8.4	4.2	39	–	–	–	–
Porichthys notatus	–	–	–	–	–	–	–	–	1.2	.1	9.1	12

* Number of stomachs containing food.

stomachs contained non-crustacean material; two contained the echiuroid worm, *Urechis caupo,* and two contained fish.

Gray smoothhounds fed primarily on crabs in Elkhorn Slough. The yellow shore crab, *Hemigrapsus oregonensis,* a small sized crab usually less than 25 mm in carapace width, was the most important food item; three species of *Cancer* crabs were also important food items. Gray smoothhounds less than 100 cm TL fed mostly on *H. oregonensis* but a medium sized crab, *Cancer gracilis,* also was an important food item. Together these two species of crabs made up more than 69% of the total volume of food consumed by gray smoothhounds less than 100 cm TL. Gray smoothhounds greater than 100 cm TL fed numerically on more *H. oregonensis* than other crabs but *Cancer productus* accounted for 54% of the total volume of food items and *Cancer antennarius* was also an important food item. *U. caupo* and ghost shrimp, *Callianassa sp.,* both burrowing forms, were present in a few gray smoothhound stomachs. This may indicate some gray smoothhounds disturb bottom sediments when feeding or possibly suck organisms from their burrows. These prey items, however, did not represent an important part of gray smoothhound food and may represent an occasional individual prey item that was eroded out of the substrate by the tides.

Mustelus henlei

Twenty-two brown smoothhound sharks (40 to 100 cm TL) were captured in Elkhorn Slough. Nineteen specimens (86%) contained identifiable food.

Brown smoothhounds fed mostly on crustaceans but fishes were of secondary importance in the diet of larger individuals (Table 2). The crabs, *H. oregonensis, C. gracilis,* and *C. productus* were the most important crustaceans eaten but shrimp, *Crangon spp.,* were also eaten. Although sample size was too small to draw any definite conclusions, some variation in the food habits of different sized brown smoothhounds was noted. *H. oregonensis* was the most important food item of brown smoothhounds less than 80 cm TL but was a minor food item of larger individuals. *C. gracilis* and *C. productus* were important food items for all sizes of brown smoothhounds and made up more than 60% of the total volume of food consumed by individuals greater than 60 cm TL. Various species of fishes and *Crangon spp.,* were also important food items of brown smoothhounds greater than 80 cm TL.

In San Francisco Bay, shrimp and crabs were the most important food items of brown smoothhounds (Herald and Ripley 1951; Razyn 1952; Russo 1975). Apparently crustaceans are the most important food items of brown smoothhounds in shallow coastal embayments.

Rhinobatos productus

The stomachs of 82 shovelnose guitarfish that ranged in size from 60 to 150 cm TL were examined. Seventy-eight (95%) stomachs contained food (Table 3).

Shovelnose guitarfish fed mostly on crustaceans in Elkhorn Slough, with *H. oregonensis* being the most important food item. When differences in food habits did occur between size classes, it was generally due to the presence of fishes or clams in the stomach contents. Fishes formed a consistent, although minor, part of the food of shovelnose guitarfish 90 to 120 cm TL. Several species

TABLE 2. Percent Number (%N), Percent Volume (%V), Percent Frequency of Occurrence (%F.O.), and Index of Relative Importance (IRI) of Food Items in the Diet of Brown Smoothhounds, 40 to 100 Cm Total Length, Captured in Elkhorn Slough, Monterey Bay, California.

	Total length (cm)											
	*40–59.9 (2)**				*60–79.9 (6)**				*80–99.9 (11)**			
Food item	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*
Crustacea (Total)	100	100	100	20000	100	100	100	20000	74.1	94.7	90.9	15344
Crangon sp.	–	–	–	–	17.2	6.7	33.3	796	25.9	4.1	45.5	1365
Cancer gracilis	15.0	21.2	50.0	1810	10.2	20.3	50.0	1525	14.8	30.5	18.2	824
Cancer productus	10.0	20.0	50.0	1500	17.2	41.6	50.0	2940	14.8	51.9	27.3	1821
Hemigrapsus oregonensis	75.0	58.8	100	13380	55.6	31.7	50.0	4365	14.8	4.7	36.4	710
Blepharipoda occidentalis	–	–	–	–	–	–	–	–	3.7	3.5	9.1	65
Cephalopoda												
Loligo opalescens	–	–	–	–	–	–	–	–	3.7	.9	9.1	42
Pisces (Total)	–	–	–	–	–	–	–	–	22.2	4.4	36.4	968
Engraulis mordax	–	–	–	–	–	–	–	–	7.4	1.8	9.1	84
Gillichthys mirabilis	–	–	–	–	–	–	–	–	3.7	.3	9.1	36
Bothidae	–	–	–	–	–	–	–	–	3.7	.3	9.1	36
Unidentified fishes	–	–	–	–	–	–	–	–	7.4	2.0	18.2	171

* Number of stomachs containing food.

TABLE 3. Percent Number (%N), Percent Volume (%V), Percent Frequency of Occurrence (%F.O.), and Index of Relative Importance (IRI) of Food Items in the Diet of Shovelnose Guitarfish, 60 to 150 Cm Total Length, Captured in Elkhorn Slough, Monterey Bay, California.

	Total length (cm)											
	60–89.9 (6)*				90–119.9 (55)*				120–149.9 (17)*			
Food item	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*
Polychaeta	–	–	–	–	.6	.6	3.6	4	–	–	–	–
Echiuroidea												
Urechis caupo	–	–	–	–	.3	2.2	1.8	5	–	–	–	–
Crustacea (Total)	94.8	96.6	100	19140	86.9	70.6	90.9	14316	94.1	94.2	94.1	17719
Crangon sp.	31.6	13.3	33.3	1495	1.8	.8	10.9	28	2.4	1.0	5.9	20
Cancer gracilis	–	–	–	–	3.9	4.4	12.7	105	2.3	4.1	5.9	38
Hemigrapsus oregonensis	63.2	83.3	83.3	12203	80.9	65.2	89.1	13017	83.5	84.0	88.2	14773
Hemigrapsus nudus	–	–	–	–	.3	.1	1.8	1	5.9	5.1	5.9	65
Mollusca												
Clams	–	–	–	–	2.4	7.7	14.5	146	4.7	5.2	17.6	174
Pisces (Total)	5.3	3.3	16.7	144	9.9	18.9	30.9	889	1.2	.5	5.9	10
Cymatogaster aggregata	–	–	–	–	.3	2.5	1.8	5	–	–	–	–
Gillichthys mirabilis	–	–	–	–	1.5	2.5	7.3	29	–	–	–	–
Leptocottus armatus	–	–	–	–	1.8	5.5	9.1	66	–	–	–	–
Atherinidae	–	–	–	–	2.7	3.4	5.4	33	–	–	–	–
Bothidae	–	–	–	–	2.4	3.7	3.6	22	–	–	–	–
Unidentified fishes	5.3	3.3	16.7	144	1.2	1.3	7.3	18	1.2	.5	5.9	10

* Number of stomachs containing food.

of fishes were eaten, representing both bottom and midwater forms. Clams were also found in several stomachs. All clams were completely absent of shells and specific identification was not possible.

Apparently, shovelnose guitarfish took most of their food directly off the surface of mudflats. Because of their adaptation for a benthic life, guitarfish are probably not adept at actively pursuing midwater fishes and capturing them. Although most species of fishes eaten were primarily benthic, a few midwater forms, consisting mostly of atherinids, were eaten. In Elkhorn Slough, however, atherinids commonly fed on benthic material (Nybakken, Cailliet, and Broenkow 1977) and shovelnose guitarfish possibly captured them on the bottom.

Myliobatis californica

The stomachs of 310 bat rays (20 to 140 cm DW) were examined. Identifiable food was found in 282 (91%) stomachs.

Small bat rays fed almost entirely on clams but, as they increased in size, the echiuroid worm, *U. caupo,* became an important food item (Table 4). There was a transition from clams as the major food source to *U. caupo* as the most important food item in bat rays greater than 80 cm DW. Nevertheless, clams remained an important food source for larger bat rays. In general, the size of clams eaten varied directly with the size of bat ray. The smallest bat rays fed on very small clams, and many stomachs contained 20 or more clams along with numerous small shell fragments. The largest bat rays fed on large clams but the number found per stomach was usually less than five and shell fragments were rarely present. All identifiable clams found in stomach contents were the gaper clam, *Tresus nuttallii.* Presumably, several other species of clams were also eaten but, due to the absence of all but small shell fragments, specific identification was not possible.

Crustaceans did not form a large part of bat ray food in Elkhorn Slough. Nevertheless, crustaceans were a consistent food source for many sizes of bat rays and *H. oregonensis, C. gracilis,* and *Callianassa californiensis* were commonly found in stomachs.

Several species of fishes, representing both bottom and midwater forms, were found in a number of larger bat rays but represented a minor portion of total food consumed.

The food habits of bat rays in Elkhorn Slough differed somewhat from rays observed in other localities. Limbaugh (1955) stated that in the rocky environment of kelp beds near La Jolla, California, bat rays fed largely on shellfish including abalone and snails. Ridge (1963) and Karl and Obrebski (1976) found that small bat rays in Tomales Bay, California, fed mostly on polychaete worms, whereas large rays fed mostly on large clams and echiuroid worms.

CONCLUSIONS

Most elasmobranchs examined apparently fed in Elkhorn Slough and not Monterey Bay. Food items such as *U. caupo* and *H. oregonensis* are associated with mudflats and rarely occur in sandy substrates such as are generally found in the Bay (MacGinitie 1935). *Blepharipoda occidentalis* and *Cancer magister,* however, are usually not found in Elkhorn Slough but are common in the Bay. The presence of these species in the stomachs of a few elasmobranchs suggests

TABLE 4. Percent Number (%N), Percent Volume (%V), Percent Frequency of Occurrence (%F.O.), and Index of Relative Importance (IRI) of Food Items in the Diet of Bat Rays, 20 to 140 Cm Disc Width, Captured in Elkhorn Slough, Monterey Bay, California.

	Disc width (cm)											
	20–39.9 (61)*				40–59.9 (120)*				60–79.9 (49)*			
Food item	%N	%V	%F.O.	IRI	%N	%V	%F.O.	IRI	%N	%V	%F.O.	IRI
Nemertea	–	–	–	–	–	.8	4.2	3	–	.3	2.4	1
Annelida												
Polychaeta	–	–	–	–	.4	1.3	4.2	7	.5	.3	6.1	5
Hirudinea	–	–	–	–	–	–	–	–	.2	.1	2.0	1
Echiuroidea												
Urechis caupo	–	–	–	–	.9	8.1	9.2	83	12.1	45.4	44.9	2582
Listriolobus pelodes	–	–	–	–	.3	.5	1.7	1	.2	.5	2.0	1
Crustacea (Total)	.7	2.9	8.2	29	2.5	6.7	25.8	237	3.7	6.9	34.7	368
Crangon sp.	.6	2.4	6.6	20	.2	.3	1.7	1	.2	.1	2.0	1
Cancer gracilis	–	–	–	–	.1	.1	.8	<1	–	–	–	–
Hemigrapsus oregonensis	.1	.5	1.6	1	1.7	5.3	19.2	134	2.1	2.2	22.4	96
Pinnixa sp.	–	–	–	–	.3	.2	.8	<1	.7	.4	4.1	5
Unidentified crab parts	–	–	–	–	–	.4	3.3	1	–	1.6	12.2	20
Blepharipoda occidentalis	–	–	–	–	.1	.3	.8	<1	–	–	–	–
Callianassa californiensis	–	–	–	–	.1	.1	.8	<1	.7	2.6	8.2	27
Mollusca												
Clams	99.3	97.1	96.7	18992	95.5	78.8	90.0	15687	81.8	40.8	73.5	9011
Pisces (Total)	–	–	–	–	.8	3.5	8.3	36	1.7	5.5	16.3	117
Clupea harengus pallasi	–	–	–	–	–	–	–	–	.3	4.1	4.1	18
Clevelandia ios	–	–	–	–	.2	.3	2.5	1	–	–	–	–
Gillichthys mirabilis	–	–	–	–	–	–	–	–	.3	.5	4.1	3
Atherinidae	–	–	–	–	.4	1.9	3.3	7	.2	.1	2.0	1
Unidentified fishes	–	–	–	–	.2	1.3	2.5	4	.9	.8	6.1	10

* Number of stomachs containing food.

TABLE 4—Continued

	Disc width (cm)											
	80–99.9 (28)*				100–119.9 (19)*				120–139.9 (5)*			
Food Item	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*	*%N*	*%V*	*%F.O.*	*IRI*
Echiuroidea												
Urechis caupo	53.6	60.6	64.3	7343	43.6	43.6	68.4	5964	51.5	36.7	60.0	5292
Crustacea (Total)	6.3	7.3	42.8	582	9.6	7.9	36.8	644	6.1	5.9	40.0	480
Crangon sp.	1.5	.7	3.6	8	–	–	–	–	–	–	–	–
Cancer antennarius	–	–	–	–	.7	.2	5.3	5	–	–	–	–
Cancer gracilis	.5	.4	3.6	3	4.5	2.8	15.8	115	6.1	4.2	20.0	206
Hemigrapsus oregonensis	1.4	.6	10.7	21	2.2	.2	15.8	38	–	–	–	–
Unidentified crab parts	–	3.6	17.8	64	–	–	–	–	–	1.7	20.0	34
Blepharipoda occidentalis	1.0	.8	3.6	6	2.2	4.7	10.5	72	–	–	–	–
Callianassa californiensis	.9	.7	7.1	11	–	–	–	–	–	–	–	–
Emerita analoga	1.0	.5	3.6	5	–	–	–	–	–	–	–	–
Mollusca												
Clams	37.2	31.2	42.8	2928	31.6	28.3	73.7	4415	42.4	57.4	80.0	7984
Mytilus edulis	.5	.4	3.6	3	–	–	–	–	–	–	–	–
Fish eggs	.5	.2	3.6	2	–	–	–	–	–	–	–	–
Pisces (Total)	1.9	.4	10.7	25	15.0	20.2	31.6	1112	–	–	–	–
Engraulis mordax	–	–	–	–	6.8	5.4	5.3	65	–	–	–	–
Cymatogaster aggregata	–	–	–	–	3.7	4.9	5.3	46	–	–	–	–
Atherinidae	–	–	–	–	1.5	9.5	10.5	116	–	–	–	–
Citharichthys sp.	1.4	.2	7.1	11	–	–	–	–	–	–	–	–
Unidentified fishes	.5	.2	3.6	3	3.0	.4	10.5	36	–	–	–	–

* Number of stomachs containing food.

that these food items were eaten in Monterey Bay or at the mouth of Elkhorn Slough shortly before the elasmobranchs were captured at the study site.

Inferences from stomach contents indicate that elasmobranchs used several feeding strategies in Elkhorn Slough. The two most important strategies were the pursuit and capture of prey on the surface of mudflats and actively digging or removing burrowing invertebrates from mudflats. Presumably gray smoothhounds, brown smoothhounds, and shovelnose guitarfish almost totally restricted their feeding to the pursuit and capture of crustaceans on the surface of mudflats, whereas bat rays dug burrowing clams and echiuroid worms from the substrate.

The results of this study and information provided by Talent (1976) indicate that elasmobranchs are major predators of invertebrates in Elkhorn Slough and presumably fill major predatory roles in the community structure of this embayment.

ACKNOWLEDGMENTS

I thank C. E. Bond and G. M. Cailliet for critically reviewing the manuscript; and A. Staebler and M. Silver for their suggestions during the investigation. I thank J. Cohen, J. Cross, D. Lewis, G. McDonald, D. Varoujean, and E. Yarberry for assistance in collecting specimens. I especially thank C. Talent for assistance in all areas of the study.

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Calif. Fish and Game 68(4): 235–243 1982

THE OCCURRENCE OF SELECTED INFECTIOUS DISEASES IN THE DESERT BIGHORN SHEEP, *OVIS CANADENSIS CREMNOBATES,* HERDS OF THE SANTA ROSA MOUNTAINS, CALIFORNIA [1]

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The potential for diseases reported herein is the result of the first serological survey of free-ranging desert bighorn sheep conducted in the Southwestern United States. Antibody activity was found in 80% of the animals examined. Antibody response to contagious ecthyma, blue-tongue, and epizootic hemorrhagic disease was observed in 73, 50, and 33% of the bighorn sheep, respectively. No viremic animals were detected. Antibody to parainfluenza-3, bovine virus diarrhea, and infectious bovine rhinotracheitis was not found in any of the bighorn sheep tested. More extensive and inclusive disease studies are necessary before final conclusions are developed concerning the major population decline observed.

INTRODUCTION

Natural fluctuations in wild animal numbers occur commonly in most populations that are regulated around limited resources (Jordan, Batkin, and Wolfe 1971; Williamson 1972; Moen 1973). Therefore, it is not surprising that bighorn sheep, *O. canadensis,* populations are characterized by similar variations in population numbers. Since predation, accidents, etc., represent rather constant forces which apparently do not have significant consequences to bighorn sheep populations (Honess and Frost 1942), density dependent factors, such as disease, could have a profound influence on populations of such a highly gregarious species.

Although diseases historically have been regulatory agents in bighorn sheep populations, their effects have been greatly enhanced by the encroachment of man into ancestral and, more recently, contemporary bighorn habitat. The result has been the introduction, either directly or indirectly, of new diseases and parasites, which have worked in concert with existing habitat and environmental conditions and stress to contribute to the general decline observed in North American bighorn sheep populations.

Significant reductions in virtually all bighorn populations of western North America during the last century have been attributed to disease. Although the scabies mite, *Psoroptes* spp., has been the applied focus for several population declines of bighorn in western states (Hornaday 1901; Ward 1915; Honess and Frost 1942; Packard 1946; Jones 1950; Smith 1954; Lange, Sandoval, and Meleney 1980), the evidence is conjectural. Respiratory diseases appear to be ubiquitous in all bighorn sheep populations. Indeed, bighorn sheep appear to be predisposed to lung ailments. Pneumonia, of one form or another, has been symptomatically described from both northern and southern populations (Rush 1927; Mills 1937; Potts 1937; Marsh 1938; Honess and Frost 1942; Pillmore 1954; Russo

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1956; Buechner 1960; Welles and Welles 1961; Post 1962, 1971; Allen 1964, 1971; Forrester and Senger 1964; Light, Winter, and Graham 1967; Helvie and Smith 1970; Wilson 1975; Russi and Monroe 1976; Taylor 1976) and is considered to be the most significant disease occurring in Rocky Mountain bighorn sheep, *O. c. canadensis,* (Buechner 1960).

Despite the many reports of disease in bighorn sheep, most relate only to the Rocky Mountain ecological race, are coincidental with the collection of other biological data or hunter returns and/or are related to captive populations. The pathogens are usually only isolated from captive bighorn and not from free-ranging animals. Attempts to do so in free-ranging animals have been previously unsuccessful (Woolf, Kradel, and Bubash 1970).

The lungworm, *Protostrongylus* spp., complex is typically found in Rocky Mountain bighorn populations inhabiting the more northern latitudes and higher elevations. Within these populations, the lungworm-pneumonia complex (verminous pneumonia) is considered by many to be the major critical limiting factor. However, evidence suggests that factors other than lungworm (i.e., *Pasteurella* spp.) are at least as important as a population regulatory agent.

Southwestern desert bighorn sheep populations are generally thought to be free from the lungworm-pneumonia association and its effects (Russo 1956; McQuivey 1978). This is presumably due to aridity and the resultant lack of habitat for the nematodes' intermediate host(s). Symptomatically, lungworm infections have been described in isolated desert bighorn sheep populations. However, few investigations have substantiated these suspicions (Buechner 1960; Welles and Welles 1961; Allen 1971; Russi and Monroe 1976).

Respiratory ailments other than those associated with lung nematodes have been described in all age classes of desert bighorn sheep and have been implicated as a cause of high mortality of the lamb-yearling cohort (Russo 1954; Welles and Welles 1961; Light, Winter, and Graham 1967; Helvie and Smith 1970; Wilson 1975; Taylor 1976). Although detailed investigations are lacking, bacterial and viral agents in concert with stress are principally suspect in the etiology of the desert bighorn sheep pneumonia syndrome. Although many potentially pathological agents are not directly associated with pneumonia, they may either contribute to reduced resistance to pneumonia in the bighorn or act as secondary pathogens. Para-influenza-3 (PI-3), bovine virus diarrhea (BVD), infectious bovine rhinotracheitis (IBR), contagious ecthyma (CE), blue-tongue (BT), and epizootic hemorrhagic disease (EHD) have frequently been either primarily or secondarily implicated with pneumonia. Most often pneumonia stems from bacterial pathogens including: *Mycoplasma* spp., *Pasteurella* spp., *Pseudomonas* spp., *Corynebacterium* ssp., *Staphylococcus* spp., *Streptococcus* spp., *Diplococcus* spp., and *Neisseria* spp. (Newsom 1952; Connell 1954; Pillmore 1954, 1958, 1961; Russo 1954; Moulton 1961; Bingham 1962; Hadlow and Jellison 1962; Howe 1962; Post 1962, 1971; Luedke *et al.* 1964; Bruner and Gillespie 1966; Howe, Woods, and Marquis 1966; Robinson *et al.* 1967; Helvie and Smith 1970; Fletch and Karstad 1971; Al-Aubaidi *et al.* 1972; Parks *et al.* 1972; Smith, Jones, and Hunt 1972; Crempien, Weis, and Crenshaw 1973; Parks and England 1974; Barrett and Chalmers 1975; Samuel *et al.* 1975; Lopez, Thomson, and Savan 1976; Taylor 1976).

The objective of this study was to determine the prevalence of pneumonia and selected diseases in Peninsular desert bighorn sheep, *O. c. cremnobates,* of

southern California's Colorado desert, and to suggest a spectrum of diseases for which a surveillance can be established and maintained. All races of California's bighorn sheep have been legislatively protected since 1873. Although the protection was originally prompted by a widespread population decline, the total number of bighorn in the State has continued to decrease, with some herds becoming extirpated (Weaver 1975). The Santa Rosa Mountains in Riverside County has, perhaps, the densest population of Peninsular bighorn sheep in the State. The population has been studied intensively for more than a decade. The increasing population has had a stable age distribution and affords a potential nucleus for transplanting bighorn to suitable historic habitat. The assessment of disease within this population will provide an objective basis of measuring the potential for introducing disease into other bighorn sheep populations as well as evaluating the survival potential of bighorn subjected to the stress of transplantation.

MATERIALS AND METHODS

Ten free-ranging and one captive desert bighorn sheep were immobilized on the east slopes of the Santa Rosa Mountains, Riverside County, California. The study area is principally delineated by California State Wildlife Refuge 4D and the University of California's Philip L. Boyd-Deep Canyon Desert Research Center (see Turner 1981 for complete description of the study area and captive animal populations). Bighorn sheep were located and immobilized from either a Bell Jet Ranger or supercharged Bell B-1 helicopter with a scope mounted CO_2 Cap-Chur rifle. Animals were immobilized with 5 mg of etorphine hydrochloride (M99), and blood was taken from immobilized animals by jugular venipuncture, placed in heparinized, EDTA-treated and serum vacutainers, and refrigerated until further processing. Additionally, deep nasal cultures were taken with sterile cotton swabs and maintained in refrigerated charcoal extending media. Fecal samples were obtained and refrigerated until examined. Animals were weighed to the nearest 0.1 kg, heart and lung functions were evaluated by ausculation and physical anomalies noted. Bighorns were measured and aged by the horn ring technique (Geist 1966) and dental replacement pattern for the Santa Rosa Mountain bighorn sheep population (J. C. Turner, unpubl. data). Before reversal of the M99 with 10 mg of diprenorphine (M50-50), each animal was fitted with a numbered, blue vinyl collar, a numbered aluminum ear tag, and the dart wound treated topically with nitrofurazone spray. A combiotic, 1 M units procain penicillin/1.25 g streptomycin, was given prophylactically.

Viral attenuating media, 5 g potassium oxalate; 5 ml phenol; 500 ml glycine; 500 ml distilled water (OPG) was added 1:1 to 5 ml of heparinized blood. Phosphate buffered saline washed erythrocytes, OPG blood, and serum were sent to the U.S. Department of Agriculture's Veterinary Laboratory in Ames, Iowa, for determining antibody titer of BT, EHD, and CE by complement fixation and immunodiffusion. Virus isolation of BT and EHD was accomplished by intravenous inoculation of embryonated chicken eggs and Vero roller cell cultures, respectively.

Additional heparinized blood and serum samples were sent to the U.S. Department of Agriculture's Veterinary Services Diagnostic Laboratory in San Gabriel, California, to be examined for *Leptospira pomona, L. hardjo, L. grippotyphosa, L. icterohemorrhagiae, L. canicola,* and *Brucella abortus* by plate

agglutination and serum neutralization testing for IBR, BVD, and PI-3, respectively. Bacteria were cultured and identified from nasal swab and blood chemistries and differential blood cell counts were performed using standard clinical techniques at Valley Clinical Laboratory facilities, Palm Desert, California. Ova and parasites from fecal samples were identified at the Desert Animal Hospital, Palm Springs, California.

Bighorn sheep were immobilized in January and those individuals showing significant serum titers were recaptured in June and blood samples taken. Additionally, the population was monitored by ground and aerial survey in the vicinity of several waterholes within the study area each July from 1975 to 1980. Animals from each herd were marked with a Nel-Spot CO_2 marking pistol or a CO_2 Cap-Chur rifle employing modified darts (Turner 1982). Movements of bighorn sheep between waterholes, herd association of specifically marked animals, and population levels and trends were documented.

RESULTS

Prior exposure to viruses was indicated by antibody titers in 80% of the free-ranging bighorn sheep immobilized (Table 1). Seventy percent of the bighorn reacted to CE; however, three animals showed only suspect levels of antibody activity ($\geq$1:5, $\leq$1:10). The remaining bighorn sheep reacted strongly and the three retested showed a two-fold to four-fold increased antibody titer in the second sample. This increase suggests a recent exposure to the virus. The lowest antibody titers were confined to yearling bighorn sheep sampled in early spring, whereas the highest titers were observed in bighorn sheep older than 3 years-of-age sampled during early summer. Although titers of 1:80 were measured, no clinical symptoms of CE were apparent. Attempts at virus isolations were negative.

TABLE 1. Positive Serological Results from 10 Free-ranging and 1 Captive Desert Bighorn Sheep (Y), from the Santa Rosa Mountains, Riverside Co., California

Collar No. and immobilization date	*Age (years)*	*Sex*	*Weight (kg)*	*BT* [1]	*EHD* [1]	*CE* [1]	*Br.* [2]	*Leptospira* [2] *pomona*	*hardjo*
1. (1/ 3/77)	1	F	50.0	AC [3]	— [4]	—	—	—	—
2. (1/ 3/77)	2	F	45.4	—	—	1:40	—	—	—
(6/11/77)				—	—	1:80	—	—	—
3. (1/ 3/77)	5½	F	47.7	1:20	1:20	1:20	—	—	—
(6/11/77)				1:20	1:20	1:40	—	—	—
4. (1/ 3/77)	4½	F	43.2	1:80	—	1:20	—	—	—
(6/11/77)				1:80	AC	1:80	—	—	—
5. (3/25/77)	1	F	50.0	AC	AC	—	—	—	—
6. (3/25/77)	6	F	67.2	—	—	1:10	—	—	—
7. (3/25/77)	2½	M	63.6	—	—	1:5	—	—	1:128
8. (3/25/77)	3	M	68.2	AC	AC	1:10	—	—	—
9. (3/25/77)	5	F	68.2	1:5	1:5	1:5	—	—	—
10. (6/11/77)	3	M	59.1	—	—	1:20	—	—	—
Y. (1/ 3/77)	2	F	48.2	1:40	—	—	1:50	1:128	—
(3/25/77)				1:20	1:5	—	1:50	1:128	—
(6/11/77)				1:20	1:20	—	1:50	1:128	—

[1] Antibody titers for blue-tongue (BT), epizootic hemorraghic disease (EHD) were determined by complement fixation

[2] Plate agglutination was used to test for *Leptospira pomona, L. hardjo,* and *Brucella* spp. (Br)

[3] Anticomplementary sera (AC) were examined by immunodiffusion, all were negative

[4] No reaction values (—) at lowest dilution tested.

Fifty percent of the bighorns examined produced a reaction to BT, only one of which was considered suspect. The remaining titers were in excess of 1:20 and considered positive for BT. Virus isolation attempts were negative and second serum samples were of static or declining antibody titers.

Although 33% of the examined bighorn showed positive reactions for EHD, two animals were classified as suspect and only one bighorn was considered an EHD reactor by bovine standards. Subsequent samples revealed no significant change and the virus isolations were negative.

Plate agglutination tests resulted in positive reactions for leptospirosis in two bighorn sheep. Serum titers from both animals were 1:128 to *L. pomona* or *L. hardjo* serotypes. A subsequent sample from one animal yielded a static antibody titer to *L. pomona*. The serum from the same bighorn reacted positively (1:50) against the *Brucella* spp. antigen. The titer was constant in two subsequent samplings (Table 1).

None of the bighorn examined gave positive reactions to serum neutralization testing for IBR, PI-3, and BVD. Nasal swabs yielded normal bacterial flora except for animal #3, from which *Pasteurella* spp., *Clostridium* spp., and *Streptococcus* spp. were isolated in addition. Blue-tongue and EHD virus isolation attempts were negative.

Clinical signs of disease, subsequently elaborated by laboratory analysis, were not evident in any of the bighorns examined. Generally, the animals appeared normal and in good to excellent condition. Moist, crepitant rales were heard on ausculation of the lungs for 30% of the animals examined. No correlation was observed between animals exhibiting lung congestion and antibody titers for the disease agents tested. Bighorn #3 exhibited bilateral rales and yielded potentially pathogenic microflora from its nasal swabs. All fecal analyses for ova and parasites were negative for lung-worm and were otherwise normal.

A catastrophic decline of lambs and yearlings commenced in 1977 (Table 2). Of the only three bighorn yearlings observed in 1977 (2 female, 1 male), one ewe exhibited a bilateral, mucopurulent, nasal discharge accompanied by a moist cough, stridulous respirations, and a rough pelage; the second ewe was observed (repeatedly) to have a persistent and heavy nasal discharge and rough coat. In 1978, lambs were observed within the study area, but were earlier and smaller than normal. By 1 August, no lambs were observed. Lamb production appeared normal in 1979 and 1980; however, by 1 August the lamb recruitment was less than 50% of the 1975–76 rates.

TABLE 2. Lambs per 100 Ewes and Yearlings Per 100 Ewes Ratios for the 1974–1980 Period (End of July Censuses).

Year	*Lambs/100 ewes*	*Yearlings/100 ewes*
1975	65	47
1976	70	42
1977	0	3
1978	0	0
1979 *	27*	6*
1979	12	1
1980 **	1**	1**

* Helicopter survey, California Department of Fish and Game, 6/24/79.
** Census for end of June 1980.

DISCUSSION

The existence of viral and bacterial pathogenesis in the Santa Rosa Mountain bighorn sheep herds revealed in this study was diagnosed from seriological patterns and not from classic clinical pathognomonic evidence. Indeed, all animals immobilized during the investigation were clinically normal in both physical and behavioral attributes. Although no viremia or active pathology attributable to the diseases was found, no recognized surveillance and laboratory diagnostic services currently operate on the bighorn herds. Therefore, the infrequent observations made were insufficient to allow detection of any subclinical infections from seasonally occurring diseases. Coincident with subclinical disease is the possibility of reservoir host animals infecting the population. These diseases could become evident during periods of stress, i.e., increased or decreased population lèvels, reproductive activity, low nutrient availability, and/or climatic severity.

The absence of antibodies for IBR, PI-3, and BVD suggest nonexposure and perhaps non-susceptibility. Antibody titers to PI-3 were measured in a bighorn sheep from the San Gabriel Mountains of Los Angeles and San Bernardino counties, 129 km north of the Santa Rosa Mountain herds (C. Jenner, veterinarian, Rossmore-El Dorado Animal Hospital, Los Alamitos, CA, pers. commun.) Although the relationship between PI-3 and pneumonia is not completely understood, the association of PI-3 with pneumonia is well documented (Howe *et al.* 1966; Parks *et al.* 1972). Bovine virus diarrhea and IBR are typically infectious diseases of cattle. The incomplete understanding of their transmission under natural conditions and effects in wild bovids should not exclude them from future surveillance schedules.

The prevalence of low antibody titers for BT and EHD (Table 1) implies a temporary focus of virus activity and does not prove enzootic maintenance of these viruses. The origin(s) of the high frequency of low antibody activity to the CE virus in the absence of clinical symptoms and domestic sheep or goat contact is uncertain. It suggests the occurrence of a chronic subclinical level of infection within the population or perhaps, the presence of reservoir host individuals.

However, BT and EHD are agents whose vector is a biting midge, *Culicoides* spp. Although the midge occurs seasonally throughout much of its distribution, little is known of its range and seasonality in nonagricultural desert areas (Saul Frommer, Curator, Entomol. Mus. Univ. of Calif., Riverside, CA, pers. commun.). The infrequency or absence of sustained frosts and their regulatory effect on the midge could contribute to the seasonality of the BT and EHD antibody titers.

Presence of both leptospirosal and *Brucella* spp. antibodies in wild sheep suggests contact with infected cattle or some other bovid species. However, no recent (20–25 years) contact can be documented. Cattle are maintained at considerably higher elevations during the spring and summer in the Santa Rosa Mountains and are generally assumed to be outside bighorn habitat. Formerly, cattle ranged into the meadows of the upper elevations of bighorn habitat.

Several important questions should be considered relative to the diagnosis of any pathogen in the free-ranging bighorn sheep of the Santa Rosa Mountains. Foremost, how did the organisms become entrenched in this herd? And, to what extent is the herd affected? Certainly the possibility of contact with infected domestic livestock cannot be eliminated. The close proximity of human habita-

tion, agricultural development of the nearby Coachella Valley, increased recreational use of marginal and prime bighorn habitat, including equestrian and hiking trails, and an increasing resident human population provides a model biocenose for the intercalation and maintenance of potentially catastrophic diseases. The prevalence of the disease agents found within this study only suggests that the potential for pathosis exists and factors not investigated may have contributed to the observed population decline. The potentially catastrophic decimation of four age classes within 3 years will not have its full effect upon the population until the lost animals would have achieved their reproductive potential.

The result of transplanting bighorn from the Santa Rosa Mountain herds without a conscientious disease surveillance schedule could have the result of infecting otherwise disease-free habitat and recipient bighorn sheep herds. Similarly, a pathogen profile should be ascertained for the recipient herd(s), to prevent loss of otherwise healthy donor animals. Additionally, the loss of animals from a cohort depleted population could locally reduce the population below its recuperative resiliency by the Allee Principal (Odum 1971).

ACKNOWLEDGMENTS

We greatly appreciate the assistance and cooperation of the California Department of Fish and Game, in particular R. Weaver and J. Harris; C. Jenner, H. Salk, S. Salk, and J. Osborn; the Wyoming Game and Fish Research Laboratory, Laramie, WY; the University of Wyoming, Department of Zoology and Physiology, Laramie, WY; the P. L. Boyd-Deep Canyon Desert Research Center, University of California, Riverside, CA; the Living Desert Reserve/Palm Springs Museum, Palm Desert, CA; Valley Clinical Laboratories, Palm Desert, CA; and the Desert Bighorn Council. This research was funded by grants and donations made to the authors by The Society for the Conservation of Bighorn Sheep, the East African Safari Club of New York, the California Department of Fish and Game, the Riverside County Board of Fish and Game Commissioners, and H. Hays, whose extra generosity was great and most appreciated.

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Calif. Fish and Game 68(4): 244–248 1982

CRUSTACEANS FROM BAITED TRAPS AND GILL NETS OFF SOUTHERN CALIFORNIA [1]

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Twenty-seven species of crustaceans were taken in baited sablefish traps, shrimp traps, and gill nets off southern California in 1969 and 1978–80. Most of them were strictly benthic or capable of swimming only short distances. Only two species of shrimp were caught in the traps. *Caprella ungulina, Axius acutifrons, Acantholithodes hispidus,* and *Glyptolithodes cristatipes* are recorded for the first time from southern California. A new host record is given for *Parapleustes commensalis.* Baited traps seem effective in attracting scavenging decapods and bringing them to the surface in good condition.

INTRODUCTION

Decapod crustaceans are among the largest animals living on the continental shelf and slope of southern California. Previous collections of these animals have been conducted with dredges, trawls, and box cores. Although these methods have captured many decapods, they allow fast-moving species to escape. The patchy distribution of many species causes sampling devices to miss concentrations of the animals. Baited traps, however, attract predatory and scavenging species. These species and their associated commensals and parasites may suffer less damage when raised to the surface in a trap than when dragged along the bottom in a dredge or a trawl.

METHODS

From 1978–80, fishermen working out of San Pedro used traps baited with chopped fish to capture sablefish, *Anoplopoma fimbria,* at depths to 1330 m. These traps often caught invertebrates as well as fish. Shrimp traps and gill nets also incidentally caught benthic crustaceans. James Phelan of the California Department of Fish and Game obtained frozen specimens from these commercial fishermen. Additional decapods were donated by William F. Samaras of Carson High School. The crustaceans were taken to the Allan Hancock Foundation for identification and storage in their collection.

Crustaceans were taken in March–September 1978, January–October 1979, and June 1980 at depths of 165–1055 m. The specimens were collected by the boats *ARISTA, BILL KENTNER, CALAFIA, CAPE BLANCO, CAROLYN L, FOOL'S DELIGHT II, GERNOMINO, JUANALOA, JJ, LAURA MICHELLE, MISS ALLISON, OCEANA, PETE BOY,* and *SALTY II.* Detailed records of all the specimens are available for examination in the card catalog of the Allan Hancock Foundation.

In 1969, crustaceans were collected off Anacapa and Santa Cruz islands in baited shrimp traps. These animals, taken at 215–269 m by the *N. B. SCOFIELD,* already had been donated to the Allan Hancock Foundation. Their records, from

[1] Accepted for publication May 1981
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lesser depths than those of the sablefish traps, provided a useful comparison of species living on the upper continental slope.

Localities for all species from the traps and gill nets are grouped into broad areas: mainland (Point Dume, Dana Point, San Onofre, and La Jolla), northern islands (from Point Conception to Anacapa, Santa Cruz, and Santa Rosa islands and their vicinity), and southern islands (San Nicolas, Santa Barbara, Santa Catalina, and San Clemente islands; Tanner and Cortez banks, and nearby banks or canyons (Table 1).

TABLE 1. Species Taken in Sablefish Traps, Shrimp Traps, and Gill Nets Off Southern California

Species	*165–500 m*	*500–1000 m*	*1000 m +*	*Mainland*	*Pt. Conception-northern islands*[1]	*Southern islands and banks*[2]
Acantholithodes hispidus (Stimpson)	X					X
Axius acutifrons (Bate)			X			X
Caprella ungulina Mayer		X				X
Chionoecetes tanneri Rathbun		X		X		X
Chirostylus sp.		X				X
Chorilia longipes turgida Rathbun	X	X				X
Galathea californiensis Benedict	X				X	
Glyptolithodes cristatipes (Faxon)	X	X		X		X
Gnathophausia ingens (Dohrn)			X			X
Lithodes couesi Benedict		X	X			X
Lopholithodes foraminatus (Stimpson)	X				X	X
Loxorhynchus crispatus Stimpson	X					X
Munida hispida Benedict	X				X	X
Munidopsis depressa Faxon		X		X		X
Munidopsis hystrix Faxon		X		X		X
Munidopsis quadrata Faxon		X				X
Munidopsis verrilli Benedict			X			X
Paguristes ulreyi Schmitt	X				X	
Pandalopsis ampla Bate			X		X	
Paralithodes californiensis Benedict		X			X	X
Paralithodes rathbuni (Benedict)	X					X
Paralomis multispina (Benedict)		X				X
Parapagurus pilosimanus benedicti de St. Laurent		X				X
Parapleustes commensalis Shoemaker		X		X		
Parapleustes sp.		X		X		
Pasiphaea pacifica Rathbun		X				X
Stereomastis sculpta pacifica (Faxon)			X		X	X

[1] Northern islands: Anacapa, Santa Cruz, and Santa Rosa Islands.
[2] Southern islands and banks: Santa Barbara, Santa Catalina, San Nicolas, and San Clemente Islands; Tanner and Cortez Banks.

RESULTS

Twenty-two of the species were taken at depths and locations well within their known ranges. Except for *Pasiphaea pacifica* and *Gnathophausia ingens,* the crustaceans tend to be strictly benthic or capable of swimming only short

distances. *Chionecetes tanneri, Chorilia longipes turgida, Galathea californiensis, Munida hispida, Munidopsis hystrix,* and *Paralomis multispina* were caught most frequently in the traps.

Five of the species taken in the sablefish traps have not been reported previously from southern California. Adults of *Stereomastics sculpta pacifica* were collected six times. An account of the range of larvae and adults of this polychelid lobster has been published elsewhere (Wicksten 1981). Records of the other four species are given below. A new host is given for one species.

Caprella ungulina Mayer

This skeleton shrimp has not been reported previously in California south of Monterey (D. Laubtiz, National Museums of Canada, pers. commun.) Two specimens were taken: one from the *JJ* on 10 May 1978, lat 32°45'N, long 118°14'W, 925 m; and another from the *JUANALOA* on 28 August 1979, off Cortez Bank, 1015 m. Both were clinging to the legs of the lithodid crab *Paralomis multispina.*

Parapleustes commensalis Shoemaker

The gammarid amphipod *Parapleustes commensalis* was described as a commensal of the spiny lobster, *Panulirus interruptus* (Randall), from Santa Barbara (Shoemaker 1952). Many of these amphipods were found on the carapace of the lithodid crab, *Paralithodes californiensis.* This crab was taken off San Onofre at 555 m in January 1979 by the boat *MISS ALLISON.*

Axius acutifrons (Bate)

The axiid lobster *Axius acutifrons* was taken twice. Two were found in the skeleton of a hexactinellid sponge taken by the *CALAFIA* on 6 September 1978, lat 32°15'N, long 119°36'W to lat 30°00'N, long 119°39'W, 1850–2310 m. An ovigerous female was collected by Dwight Chapin (California Department of Fish and Game) south of San Clemente Island (lat 32°22.5'N, long 118°38.0'W), 1108 m, 10 January 1979 (Figure 1). There are only four previous records of this lobster: off Banda, East Indies (lat 4°31'S, long 129°57'20"E), 665 m, volcanic mud, *CHALLENGER* station 194A, 29 September 1874 (Bate 1888); off Mariato Point, Panama (lat 6°30'0"N, long 81°44'0"W), green sand, 1025 m, 24 February 1891, *ALBATROSS* station 3358; off Mariato Point (lat 6°22'20"N, long 81°52'0"W), rocky bottom, 858 m, 24 February 1891, *ALBATROSS* station 3359 (Faxon 1895); and off the southeast coast of Great Kei Island (lat 5°5.5'S, long 132°47.7'E), 595 m, from hexactinellid sponge on gray mud, coral, and stones; 19 December 1900, *SIBOGA* station 226 (de Man 1925).

Acantholithodes hispidus (Stimpson)

The extremely spiny lithodid crab *Acantholithodes hispidus* has been recorded as ranging from Moorovskoy Bay, Alaska to Monterey Bay, California, to 142 m (Schmitt 1921). Three females and two males were caught in a gill net on Potato Patch Bank, off San Nicolas Island (lat 33°18.27'N, long 119° 47.60'W), 165 m, June 1980, *GALAPAGOS,* W. Samaras, collector. One of the females was ovigerous.

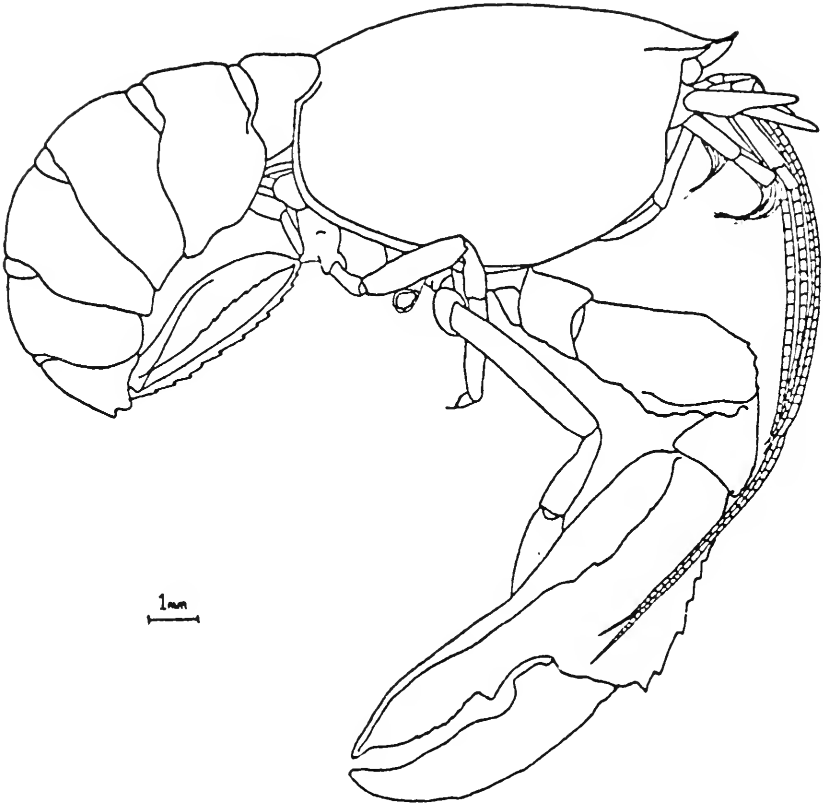

FIGURE 1. Female *Axius acutifrons* (Bate) from south of San Clemente Island, 1108 m.

Glyptolithodes cristatipes (Faxon)

This lithodid crab was collected 19 km off the east end of Santa Catalina Island, 702 m, 8 August 1979, boat *JJ*. The crab has not been reported previously from California, although there are two additional specimens from this state: an ovigerous female trawled off the Palos Verdes Peninsula (lat 33° 33.5'N, long 118° 15.7'W), 462 m, 5 March 1976, *VAN TUNA;* and at the southeast corner of Coronado Bank, 183 m, 3-chambered trap, 12 April 1969, *E. B. SCRIPPS,* R. McConnaughey (Scripps Institution of Oceanography) collector. The latter specimen is in the collections of Scripps Institution of Oceanography. Previously, *G. cristatipes* has been reported four times: off Mariato Point (lat 7°9'45"N, long 80°50'O"W), 594 m, green mud, 23 February 1891, *ALBATROSS* station 3354 (Faxon 1895); south of Banco de Mancora, Peru, mud bottom, 400 m, 1971, *SNP-1* station 7011; off northern Peru (lat 3°51'S, long 81°18'W), 800 m. 1971; and off Puerto Chicana (lat 7°42'S, long 80°26'W), 693 m, rocky bottom, 2 March 1971, *SNP-1* station 7101 (del Solar 1972). *Glyptolithodes cristatipes* may arrive in southern California only during periods of warm southern water rather than living here in permanent populations.

DISCUSSION

Deep-water animals can find bait and move to it quickly (Isaacs and Schwartlose 1975). Many of the crustaceans taken in the traps were scavengers, attracted to the bait. Others, such as *Axius acutifrons,* may have been entangled when the trap hit the bottom. Crustaceans in gill nets may have tried to eat the entangled fish.

Only two shrimps (*Pasiphaea pacifica* and *Pandalopsis ampla*) were caught in the traps. *Pandalus platyceros* Brandt and *Spirontocaris sica* Rathbun, commonly caught in trawls off southern California, were not collected. However, both of these species have been taken in shrimp traps on the shoulders of sea canyons at Santa Catalina Island by the *BILL KENTNER* at depths lesser than the fish traps (P. Gregory, Calif. Dept. Fish and Game, pers. commun.) At greater depths, the shrimp either are not often attracted to the bait or are able to escape the traps.

ACKNOWLEDGMENTS

I thank D. Laubtiz, National Museums of Canada and R. Klink and J. Haig of the Allan Hancock Foundation for aid in identifying some of the specimens. S. Goodman prepared the figure. The interest of the crews of the fishing boats is gratefully appreciated.

This work was carried out while the author held a Research Fellowship of the Allan Hancock Foundation.

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Calif. Fish and Game 68(4): 249–252 1982

STATUS AND NOMENCLATURAL HISTORY OF *AGONUS VULSUS* JORDAN AND GILBERT, 1880 (PISCES—FAMILY AGONIDAE)[1]

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The holotype of *Agonus vulsus* Jordan and Gilbert, 1880, was examined and found to be identical with *Averruncus emmelane* Jordan and Gilbert, 1895. The nomenclatural history of the species is discussed. *Agonopsis vulsa* (Jordan and Gilbert, 1880) becomes the correct binomen.

INTRODUCTION

The poacher, *Agonus vulsus* Jordan and Gilbert, 1880, was described from ". . . about ten specimens picked out of piles of prawns in the San Francisco market," but is known only from the type. The apparent rarity of *A. vulsus* from an area in which the nearshore ichthyofauna is reasonably well known led us to believe that *A. vulsus* was perhaps identifiable with some other Californian agonid; hence the holotype, USNM 27756, was examined.

Agonus vulsus is similar in meristic and morphometric characters to *Averruncus emmelane* Jordan and Starks, 1895 (= *Agonopsis emmelane* in current literature) but supposedly differed from the latter in the absence of vomerine and palatine teeth, characters which were considered not only diagnostic at the species level but also as meriting generic rank. Examination of the holotype of *Agonus vulsus* revealed both palatine and vomerine teeth. The high quality of modern optical equipment has allowed us to locate these anatomical features which escaped the original describers. Also, although the type of *A. vulsus* has been in alcohol for over 100 years, the white tips of the pelvic fins, a feature diagnostic of *Agonopsis emmelane,* are still evident. Based on the above facts, these two nominal species are considered as identical. (Figure 1).

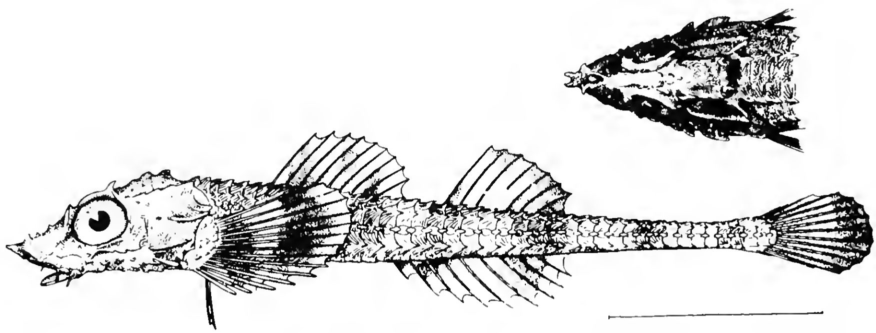

FIGURE 1. *Agonopsis vulsa* (Jordan and Gilbert). Figure of "the original type of *Stelgis vulsus*" from Jordan and Starks, 1895.

[1] Accepted for publication November 1981.

NOMENCLATURAL HISTORY

Agonus vulsus has been variously placed in five different genera since its discovery (*Agonus, Podothecus, Stelgis, Ganoideus,* and *Acanthostelgis*). In their original description of *Agonus vulsus,* Jordan and Gilbert (1880) were by no means firm in their generic placement, and state that "It belongs to the group or genus termed *Podothecus* by Professor Gill (typified by *Agonus acipenserinus*) . . . ." The species was characterized by lacking vomerine and palatine teeth, a feature which also was of prime importance in separating it at the generic level [*Podothecus* shared this feature]. Jordan and Gilbert favored *Podothecus* as the generic designation in two later papers (1881 and 1883). In 1895, Jordan and Starks implied that *Podothecus* may have been strongly favored as the proper genus when *vulsus* was originally described; placing *vulsus* in a new genus they state "Allied to *Podothecus* is the genus *Stelgis* Cramer, of which *Podothecus vulsus* is the type." [*Podothecus* dates from Gill, 1861a; the type species being *Podothecus peristethus* Gill, 1861b, which has been shown by Jordan and Evermann, 1898, to be synonymous with *Agonus acipenserinus* Tilesius, 1811.]

The most important paper relating to the existing problem is that by Jordan and Starks (1895), "The Fishes of Puget Sound", in which the genus *Stelgis* Cramer is introduced and to which *vulsus* is relegated type by original designation (p. 821). Also in this paper, *Averruncus emmelane* is described as a new genus and species (p. 821–824) and the authors state "This species is the type of a distinct genus, *Averruncus,* allied to *Podothecus,* but with teeth on the vomer and palatines." Thirdly, *Xystes axinophrys* is described as "n. gen. and sp." from a specimen 1½ inches in length (p. 824–827); "This species seems to represent a new subgeneric or generic type, allied to *Averruncus,* . . . ." These three nominal species are all illustrated in Jordan and Stark's paper in the order given above (Plates XC–XCII).

In an ichthyological survey of the San Juan Islands, Washington, Starks (1911) found *Averruncus emmelane* to be the commonest agonid from the area. Upon examining this material he noted, "Among these specimens are some small ones, which more or less completely bridge the gap between this species and *Xystes axinophrys,* making it evident that the latter form is the young of this species." Gilbert (1915), upon examination of the type of *Xystes axinophrys* also noted that "it is based on a very young individual of *Averruncus emmelane.*" With the synonymy of *X. axinophrys* and *A. emmelane* it was considered that the rare *Stelgis vulsus* and common *Averruncus emmelane* were valid and distinct species.

Stelgis vulsus was to undergo further generic shifting. Whitley (1950) in reviewing Neave's "Nomenclator Zoologicus" proposed the genus *Ganoideus* as a replacement name for *Stelgis* which was preoccupied in Invertebrata—"*Stelgis* Jordan and Starks, 1896 = *Ganoideus,* nov. (Agonidae)." Fowler (1958) apparently unaware of Whitley's genus *Ganoideus* and also recognizing that *Stelgis* was preoccupied, proposed: "*Acanthostelgis* new generic name." In the past twenty years both *Stelgis* and *Ganoideus* have been used in reference to *vulsus: Stelgis* (Fitch, 1966; Fitch and Lavenberg, 1968; Bailey et al., 1970); *Ganoideus* (Miller and Lea, 1972). To our knowledge *Acanthostelgis* has been applied only by Fowler.

Returning to *Averruncus emmelane,* we find that this species is first moved generically and listed as *Agonopsis emmelane* by the American Fisheries Society Committee on Names of Fishes (Bailey et al., 1960). The basis of this generic shift was the unpublished Ph.D. thesis of Freeman (1951) in which *Averruncus* was considered a junior synonym of *Agonopsis* Gill, 1861 (C. R. Robins, pers. comm.). In an earlier paper Gilbert (1915) had suggested that "*Averruncus sterletus* Gilbert should probably be referred to the genus *Agonopsis,* which appears to differ from *Averruncus* in the shorter vertical fins and the subequal jaws, the rostrum not conspicuously protruding. The latter character is not very important, and the two genera eventually may be united." The genus *Agonopsis* is attributed to Gill, 1861c, the type by original designation *Aspidophorus chiloensis* Krøyer [sic]. *Aspidophorus chiloensis* is rightfully a description of Jenyns (1840) from the Zoology of the Voyage of the Beagle. Hence, *Agonopsis* was applied to an agonid from the coast of Chile. The Agonidae of the southern hemisphere are known from the coasts of both Chile and Argentina and the Falkland Islands. We are aware of at least three nominal species from this region; their status is unknown to us. The genera of the family Agonidae are at present poorly understood and in need of review. It is not our intent to determine or question the generic validity of *Agonopsis* or *Averruncus.* We choose to follow current usage and treat *Agonopsis* as a genus exhibiting bipolar distribution.

STATUS

Agonus vulsus Jordan and Gilbert, 1880, is a senior synonym of *Averruncus emmelane* Jordan and Starks, 1895.

Stelgis Cramer *in* Jordan and Starks, 1895, is a junior homonym (*Stelgis* Pomel, 1872—a sponge), which according to the International Code of Zoological Nomenclature "must be rejected and replaced." *Ganoideus* Whitley and *Acanthostelgis* Fowler are replacement names for *Stelgis* Cramer.

Averruncus Jordan and Starks, *Xystes* Jordan and Starks, *Stelgis* Cramer, *Ganoideus* Whitley and *Acanthostelgis* Fowler are treated as junior subjective generic synonyms of *Agonopsis.*

Therefore, *Agonopsis vulsa* (Jordan and Gilbert, 1880) becomes the correct binomen for the species under discussion. The common name, northern spearnose poacher, is applied to this form.

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